USEFUL SCIENCE

WEED AND REXFORD

BOOK TWO

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USEFUL SCIENCE

BOOK TWO

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HOW THE AVIATOR SEES A RAINBOW

When the horizon or other obstruction does not intervene, the familiar rainbow becomes a full circle and, in cases where a secondary bow would form, a secondary circle will form also, as shown in the illustration. The shadow of the airship will fall in the center of the circle and the whole will be a striking spectacle.

USEFUL SCIENCE

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BOOK TWO

THE JOHN C. WINSTON COMPANY

CHICAGO PHILADELPHIA TORONTO
ATLANTA LOS ANGELES DALLAS

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FOREWORD

The study of science in elementary schools and junior high schools is justified because of the use that may be made of the knowledge acquired by such study.

In this series of books, the authors have aimed to supply material for teaching some of the truths about Nature's manifestations. It is hoped that through this study, pupils will recognize the universal nature of scientific truths. For example, we sit down to "cool off" after a spirited game; the garden becomes dry and parched; the tea kettle "boils dry"; snow leaves the mountain sides in the spring — all these occurrences should recall to the mind the principle of evaporation.

Experiments in science should not be allowed to appear as laboratory tricks. Experiments are introduced when questions arise that should be answered out of experience. If there are no questions to be answered in this manner, there need be no experiments. Youth is coming into world activities today more rapidly and at an earlier age than ever before. It is believed that a few telling experiments well done have more educational value than a multiplicity of experiments each of which can receive at most only cursory attention.

The table of contents is arranged in outline form in order that the teacher may use it as a ready aid in preparing lesson plans.

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Questions are interspersed throughout. It has been found by practical experience that there is great advantage in considering topics while fresh in the pupils' minds rather than in postponing the questions until a chapter is completed.

The universal query of the normal boy or girl is: "How does it work?" or, "What makes this thing go?" The authors have had these questions uppermost in their minds throughout the preparation of the book. Their aims are to simplify a few seeming scientific mysteries and to encourage and promote an attitude of intelligent investigation.

H. T. W.
F. A. R.

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USEFUL SCIENCE

CHAPTER ONE

OUR EVER-PRESENT ENVIRONMENT

1. Simple facts often teach us useful lessons. There are many everyday happenings in our environment which touch our lives. These are often so simple and so closely related to us that we pass them by without attempting to learn the lessons which they teach. In Book One of USEFUL SCIENCE, attempt was made to bring some of these happenings to your attention and to arouse a certain amount of thought about them.

2. Orderly habits are useful. No attempt was made to teach all the scientific and useful facts about the different parts of our environment. We hoped only to give you enough scientific knowledge to aid in the formation of orderly habits and to arouse your interest in the world about you so that you would want to understand still more about it.

3. We learn a little at a time. In fact, the first book tries to show us that we have a special environment in which we live and which is closely related to us. We learned a few facts about water, air, trees,

rocks, and soil; we added a little to what we had already learned in our geography, but in no case must we feel that we learned all there is to know about the different topics we studied.

Why do we often fail to learn the lessons we should from our environment?
Name some part of your environment that you have passed over without understanding it.
What part of your environment do you know everything about?

4. We live, work, and play in our environment. While this book contains much that is new, we shall find that we are still studying our environment; we are still living in the same surroundings. We hope to show you how people may get the most happiness and success out of life by adapting themselves correctly to the surroundings in which they live.

5. We continually review our knowledge of our environment. Let us not make the mistake of thinking that because in our previous year's work we learned a few scientific facts about water, we learned all about it. Experience of a great many years teaches us that the eighth-year and the ninth-year pupils are likely to say, "I've had that," and neglect to study the new material. In reality we know very little. No one can know it all, but if we add a little to our knowledge each year, we shall in time have a fair acquaintance with the surroundings in which we live.

6. What is our life work going to be? It is even hoped that as we follow this study through, we may discover the thing which is so hard for young people to settle upon; that is, "What am I going to do as my part in the work of the world?"

We shall find that it will not be sufficient to decide what we shall do as our part of the world's work. The older we grow the more we find that we have to divide our time intelligently and scientifically. As science advances in its march toward doing things faster and better, we shall find that the work of the world will consume less and less time.

It will be necessary for us not only to plan our working hours but also to organize our lives so that we may play as well as work intelligently. Our study of science should be a great help to us in arranging orderly lives for ourselves.

Why should we make intelligent plans for our leisure time?

You have already studied about water. When you read the next chapter, which is about water, why should you not say, "I have studied that"?

Think over what you hope to be when you are thirty years old, and see what scientific reasons you can give that make your choice a good one or a poor one.

CHAPTER TWO

WATER, LAND, AND HEAT

7. How and why. In our previous study of science, we learned that water is one of the most plentiful and important substances in the world. We learned something of what happens to water when it is heated and when it is cooled. We found that gravity is at all times pulling on water and making it run downhill; that water carries things along with it; that, as it rapidly flows, it tears down land in the high places and builds up land in the low places. We learned what water is and what water does, but we did not learn as much of the *how* or the *why* as is now to be our quest.

8. Why go to the beach? Why do people who live and work in towns and cities enjoy a drive to the ocean beach, the lake shore, or the river front during the warm summer evenings? Everyone knows the answer. The air is cooler by the side of a body of water than it is farther inland. Man has learned to cool himself after a hot, sweltering day by taking advantage of the beaches. Before we began the study of science, we might have been satisfied merely to know that the beaches are cool; but, since we have acquired the habit of asking questions of

Nature, we want to know why it is that it is cooler near the water (Fig. 1).

9. The temperature of beach sand and water. We do not take thermometers to the beach with us, but we all know that the sand of the water front is

Courtesy Chicago Chamber of Commerce

Fig. 1. Thousands of people in Chicago enjoy the cool breezes from Lake Michigan while bathing at this popular beach

much hotter than the water in which we bathe, although the same amount of the sun's heat beats on both the sand and the water. It is interesting to learn how much difference in temperature there is between the surface of the sand and of the water. Take two thermometers with you sometime and try it.

10. Water heats and cools less rapidly than land. When evening comes, the sun's rays are beating on

another part of the world, and the land and the water near us start to cool. The land, however, cools much more rapidly than the water. On the desert it is insufferably hot in the daytime, but, when night falls, one is glad to have a blanket.

Since water both heats and cools more slowly than land, the land which is near, or surrounded by, large bodies of water has a much more even temperature than inland places of the same latitude.

11. Bodies of water moderate climate. The sun heats both the land and the water all summer. The land gives up much of its heat each night, but the water gives up its heat very slowly. Then fall and winter come. The land has not accumulated much heat and the water which has been slowly warming during the hot months does not cool so quickly as the land. In the winter we find that the air near bodies of water is more moderate, or not so cold, as the air is farther inland. Man has learned to adapt himself to this condition, particularly in his agricultural pursuits.

Which heats the faster, land or water?
Which cools the faster, land or water?
Why has land near the ocean a more even temperature than places inland?

12. Fruits flourish near bodies of water. If you will study the Products Map in your geography, you will find that the crops which grow near bodies of

water in the temperate zone are often fruits that would not survive in a severe inland climate.

13. Uneven temperatures over land and water cause land and sea breezes. There is nearly always a breeze blowing wherever a body of water meets the land. Why is this? We have only to recall our previous study about air in motion. What makes the wind blow? We recall that warm air is light and moves upward, and cooler air flows in side-

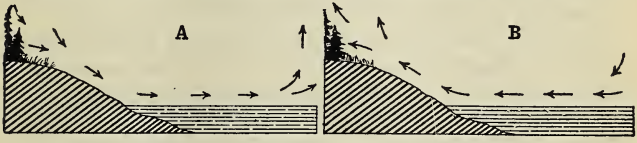


Fig. 2. A, land breeze; B, sea breeze

wise to take its place. From this we can understand that the hot air over the land moves upward and the cooler air over the water rushes in to take its place. If the air moves from the water toward the land, it is called a sea, lake, or river breeze; if it blows from the land toward the water, it is called a land breeze (Fig. 2, A and B).

14. Man works into Nature's scheme; industry follows Nature's conditions. Man makes the most of the fact that bodies of water modify or moderate the climate. Again referring to the Products Map, it will be easy to explain why fruit-canning factories are found in the region of the Hudson River, on the Pacific coast, and along the Great Lakes.

Recall and organize the facts which you have just read about temperature. Which of these facts will you need to answer the following questions?
Why is there a great grape-growing region located near the Great Lakes?
Why is the Middle West not a fruit-growing region?
What causes a land breeze? a sea breeze?
Why are fruit canneries found on the Pacific coast?

Experiment 1

Question I: Which heats more rapidly, land (earth, dirt, soil) or water?

Question II: Which cools more rapidly?

Materials: Desk apparatus. (Each desk in a well-equipped laboratory should be furnished with such simple apparatus as will be continually needed to carry on the experimental work in *Useful Science.* Many investigations can be completed without other equipment. The items in this list should include: Bunsen burner; safety matches; test tubes and test-tube stand; beaker; ring stand, rings and clamps; evaporating dish; litmus paper; asbestos square; two bread pans or similar pans about 4 inches deep.) Four quarts of dry earth; two thermometers; asbestos sheet, 18 inches square.

Directions: (*a*) Place two pans side by side on the asbestos plate on your desk. Fill one pan with water, the other with dry earth. Allow both pans to stand until the contents of each has reached the temperature of the room in which you are working.

(*b*) (Looking at a thermometer to find out the temperature is called *reading the thermometer.*) Read the temperature of the earth and the water and record in the table, page 9.

(*c*) Light two Bunsen burners and adjust the gas flow until the flames of the two burners are of the same size and thus produce practically the same amount of heat. Fasten each burner into a clamp of the ring stand. Turn the burners so that the flames will point downward at an angle of about 45 degrees. Adjust one of the flames so that it will point down-

ward on the surface of the water; place the other flame in the same relation to the surface of the pan of earth. (These flames represent the heat of the sun as it strikes the land and water surfaces of the earth.) After you have heated the surfaces of the land and water for ten minutes, remove the flames and place the bulb of a thermometer just under the surface in each pan. (We are studying the surface effect of the heat, therefore slant the thermometers so that the bulbs do not go far below the surfaces.) Read the thermometers and make the proper record in the table. Do not remove the thermometers.

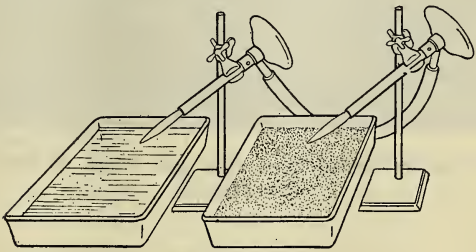
(*d*) Allow both pans to cool for ten minutes. Again read the thermometers and make the record.

TABLE

	EARTH	WATER
Temperature of earth and water at start.	.....° F.	.....° F.
Surface temperature after heating ten minutes.....	.....° F.	.....° F.
Surface temperature after cooling ten minutes.....	.....° F.	.....° F.

Diagrams: Show both pans being heated.

Conclusion: Answer Questions I and II.



Experiment 1

Practical application: Which surface heated more rapidly, earth or water? Which cooled more rapidly? Why is the dry sand at the beach often burning hot while the water is

cool? Why has New York City a more even temperature than Kansas City?

Large bodies of water, for the reason you have just learned, influence the climate of the land near them. It is for this same reason that small islands in the ocean have a more uniform temperature than inland places having the same latitude.

Photo H. Armstrong Roberts

Fig. 3. Patient fishing in a deep pool brings its own reward **(See page 11)**

CHAPTER THREE

PURE AND PLENTIFUL WATER IS PRECIOUS

15. Why does water flow? We have all stood beside a brook and admired it as it runs to the river. Some of us may have paddled in one, or have been lucky enough to catch a fish or two from some deep pool in the brook (Fig. 3). Have you ever wondered why the brook does not run dry; where the water really comes from; where it finally goes; and how it happens that this same water gushes from the faucet when one needs water in the home? Before we answer such questions as these, we should review some of the properties of water that we learned in our science work last year.

16. Properties of water. You will remember that we found water to be a colorless, tasteless *liquid*. When sufficiently cooled, it turns to *solid ice*. When heated, it turns to an invisible gas called *steam*. We learned that air can dissolve water, and that water can dissolve air. We shall use all these facts in our work this year, and we shall need in addition a few important new facts about water. The first of these is this: "Water seeks its own level."

From our early study of science, we learned that water runs downhill because of gravity's pull upon

it. As long as there is nothing to oppose it, water will continue to flow. If an obstruction, such as the bottom of a dish in a sink, or a dam in a stream, gets in its way, it will not pile up as will dirt or sand. It always spreads itself out, occupying all the space it can, and its surface is always nearly level.

Under what conditions does water exist as a solid? a liquid? a gas?
What is meant by "Water seeks its own level"?
We can have a pile of sand; why can we not have a pile of water?

17. Water seeks its level. We can understand this clearly by means of a simple experiment. Fill a teakettle with water, and notice the level of the water inside the teakettle and inside the spout (Fig. 4). The water in both is at the same level. Water has risen in the spout until it is exactly as high as the water in the kettle. That is, water seeks its own level.

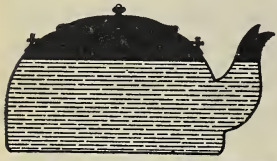


Fig. 4. Water seeks its level

18. Our whole water supply depends on this fact. Now we can understand why water runs from the faucets in our houses. Far away in the hills a reservoir is built, and from this reservoir a pipe, or an *aqueduct*, as it is called, runs to our city or village. Because the level of the water in the reservoir is higher than the level of the faucet in the kitchen,

the water, trying to rise to its original level, gushes out when the faucet is opened (Fig. 5). The greater the difference in the height of the two levels, the greater the difference in the force with which the water leaves the faucet.

19. Gravity water supply. Such a water-supply system is called a *gravity water system*, as the water flows through the pipes because of the force of grav-

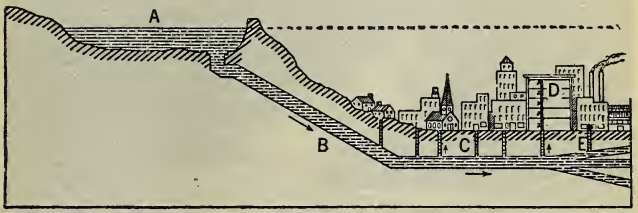


Fig. 5. Gravity water-supply system. A, reservoir on level higher than town; B, aqueduct; C, street water mains; D, faucets in dwellings; E, fire hydrant

ity. In the country a mountain stream is often dammed, and the water is piped to a farmhouse in the valley below. Pipes and aqueducts are man's means of directing the flow of water for his own use. If one lives in the country among hills and valleys, he will find many examples of this determination of water to get as far downward as possible and, if hindered, to level itself or its surface. Streams are rushing down the hillsides only to be flattened out in deep, smooth-surfaced pools when rock or stone or

sharp turns in the river banks appear in their paths. Figure 6 illustrates this tendency of water.

Courtesy Denver & Rio Grande Western R. R.

Fig. 6. The Rapids, Cañon of the Colorado River

What is meant by a gravity water-supply system?
What is the advantage of having the reservoir high above a city or town?
How may a farmer have running water in his house?
Why is the surface of a pond level?

20. Pumping systems. Suppose that you live in Chicago. You know that the city water is taken from Lake Michigan, the water level of which is below the faucet level in your house. Does it not

seem strange that this water flows from the faucet with as much force as it does from a faucet in New York, a city that gets its water from a reservoir which is many feet above the level of the city? The explanation is simple. Chicago uses large pumps that force the lake water into high *water towers* or *standpipes*. These are so high that the level of the water inside them is high enough to force water

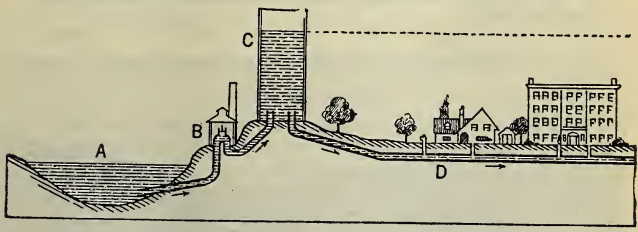
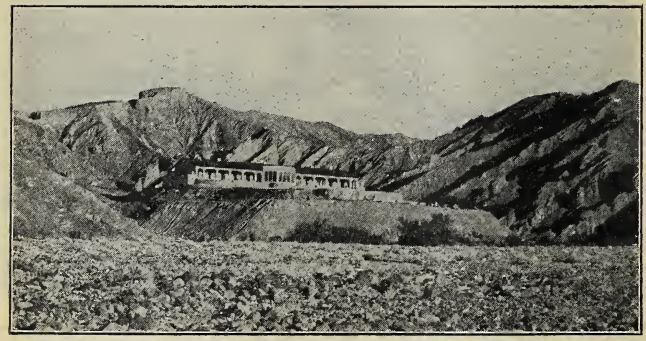


Fig. 7. Pumping water-supply system. A, reservoir; B, pumping station; C, standpipe; D, water main

through the city pipes. Such a system is a *pumping water-supply system* (Fig. 7). It is used in many places where the difference in level between the reservoir and the home is not great enough to give a good flow of water at the faucet.

21. Gravity not always enough. Even in such cities as New York, the water pressure is not great enough to supply the upper floors of tall buildings. In such cases a pump is used, and the water is pumped to a tank on the roof of the building. This gives a water level high enough to supply the building.

Contrast the principles of a pumping water-supply system and a gravity supply system.
Contrast the advantages of the gravity and of the pumping water-supply systems.
Contrast the disadvantages of the gravity and of the pumping water-supply systems.
What kind of water-supply system furnishes water to your home?
Where is a pumping water system of use?
What is a standpipe, and for what is it used?
Why do high buildings sometimes have a water tank on the roof?



Courtesy Union Pacific Railway

Fig. 8. Furnace Creek Inn, Death Valley

22. Where water is scarce. It will help you to realize the importance of a supply of good water to tell you something about places where water is scarce. Look at the package of borax that your mother has on her kitchen shelf. Note the picture of long teams of mules dragging the heavy wagon over

the desert. Death Valley, which this picture represents (Fig. 8), is between California and Nevada, and may be entered from Barstow, California. In the center of Death Valley is Furnace Creek Inn, the only inhabited spot in the valley. In the inn bathroom is posted a sign:

Newcomers MUST not waste the water. Oldtimers will not, as they know the value of water. It comes by freight.

To miss the road through the valley is to die of thirst. Under each road sign is the notice:

$1,000 FINE
or imprisonment for three years, or both, for maliciously interfering with sign or watering place.

Do you realize now the importance of water?
Where is Death Valley? What is found there?
Why is water so precious in Death Valley?

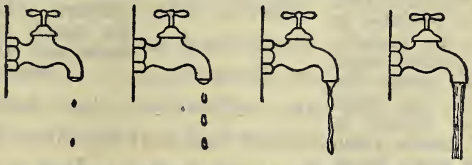


Fig. 9. The waste of water increases as the fiber washer of the faucet wears. Renew the washers when your faucet drips

23. Good water is expensive. Water is thought of as being free, but someone must pay the cost of reservoirs, aqueducts, water mains, and their maintenance. This cost is levied on us as a tax. If one wastes water (Fig. 9), the taxes will be raised. When

the faucets leak, they should be repaired. This operation is so simple that a plumber is not needed to make the repair.

24. Do not waste water. There are two usual types of water faucets in use. One closes by pulling a rubber ball against the opening from which the water comes. This is called the *Fuller faucet.* The other forces a fiber washer against the water opening by turning a handle. It is called a *compression faucet.* Both these are satisfactory, but both the rubber ball and the fiber washer wear out in time. It is a simple matter to renew them, as is shown in the diagrams, Figures 10a and 10b.

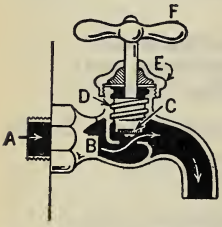


Fig. 10a. A compression faucet. A, water supply pipe; B, opening through which water passes; C, fiber washer held in place by screw (a leaky faucet can usually be corrected by replacing the washer); D, the plunger which opens and closes the faucet; E, cap which holds the plunger in place; F, handle which opens and closes faucet

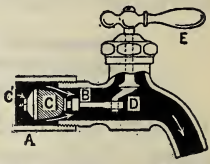


Fig. 10b. A Fuller faucet. A, water supply pipe; B, opening through which water passes; C, rubber washer held in place by nut C′ (a leaky faucet usually can be repaired by replacing this washer); D, the eccentric, attached to the handle E, which opens and closes the faucet

Why should leaky faucets be repaired at once?

Why should St. Louis charge factories 0.013 cents for a 1,000 cu. ft. of water?

Explain how you would replace the worn parts of a Fuller faucet; of a compression faucet.

25. Pure water is essential. Not only must everyone have water in plenty, but he must have *pure water*. For this reason, cities take the utmost care to protect the *watersheds;* that is, the land from which the water drains into their reservoirs. A guard is maintained so that nothing can contaminate the water supply of the city. No one is allowed to live or camp on the watershed. To make sure that the water shall be healthful, that is that it shall

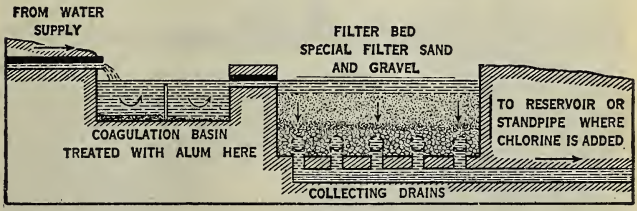
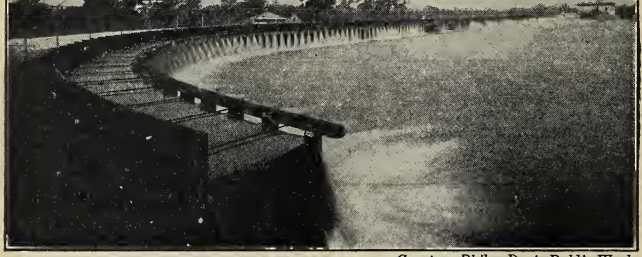


Fig. 11. Diagram showing a modern filtration process by which water is purified

contain no injurious bacteria or germs, a chemical purification is used. The chemical used is *chlorine*.

Chlorine, a yellowish green gas with an offensive odor, has the power of destroying harmful bacteria. Smell cautiously a can of bleaching powder or chloride of lime and you will learn what the odor of this gas is like. Only enough chlorine is used in the water to destroy the germs. In the process of doing this, the chlorine is altered so as to be harmless to human beings. Alum is sometimes used to coagulate or bring together the impurities, and the water

is then filtered through beds of sand (Fig. 11). This purified water is then carried by the aqueduct to the city storage reservoir, where it is forced through aëration and distribution flumes (Fig. 12). This splashing about of the water allows air to dissolve in it; the water is *aërated.* This process removes all



Courtesy Phila. Dept. Public Works

Fig. 12. Aëration and distribution flume at Queen Lane Filters, Philadelphia

odors, and improves the taste of the water. The object of all this is to supply a pure, clear drinking water.

What is a watershed?

How may improper conditions on the watershed contaminate the water supply of a city?

Explain the part that each of the following takes in the purification of water: chlorine, alum, filtering, aëration.

26. Disease germs can live in water. Many people think that if well water is clear and cold, it

must be pure. This is far from the truth. One of the main things that makes water unfit for use is the presence of such germs as those that cause typhoid fever. These germs are so small that they can be seen only by the aid of the most powerful microscope. Suppose a farmer has typhoid fever, and the countless germs that grow in his body pass from the excretions of the body into septic tanks or cesspools, and into the soil. There they multiply and, if the slope of the ground is toward the well, they finally drain into it (Fig. 13). Cows may drink the water and the germs may pass into their milk. We drink the milk and suffer an attack of typhoid fever. It is to prevent this that a strict control is maintained over the farms that supply milk for city use.

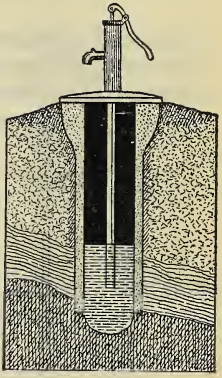


Fig. 13. This drawing shows drainage sloping away from a properly constructed well

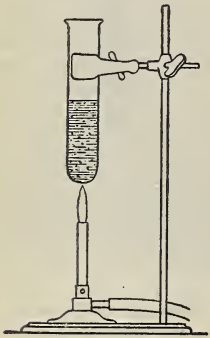
27. Take no chances. When we are compelled to use water the purity of which is doubtful, a safe rule to follow is to *boil it for twenty minutes before using.* This kills the germs that were in the water.

Why may a clear, cold water be dangerous?
How may impure water be made safe to drink?
How do impurities get into water?
How should wells and cesspools be located?

28. Water dissolves many solids. Water is always dissolving things. It may be that it is dissolving the sugar in father's morning cup of coffee, or it may be that it is dissolving the rocks that form the framework of the land.

EXPERIMENT 2

Question I: Does water evaporate in air?
Question II: Does water dissolve gases (air)?
Question III: Does water dissolve materials from the ground?


Experiment 2

Directions: (*a*) Wet a towel and hang it up so that the towel is exposed to the air. Examine it after thirty minutes. 1. What has happened to the towel? 2. What has the air done to the water that was on the towel? 3. Why has the water become invisible?

(*b*) Half fill a test tube with water. Warm the water gently. 1. What do you see rising in the water in the test tube? 2. What does this show about the ability of water to dissolve gases (air)?

(*c*) Place a few drops of filtered water from the faucet on a small, clean, tin plate. Heat the plate until the water has all disappeared. 1. What do you find left on the plate? 2. What does this show about the ability of water to dissolve materials from the ground?

(*d*) Half fill a test tube with water. Add one-half teaspoonful of sugar and shake. 1. What has become of the sugar? 2. What name do we give to this process?

Diagrams: Show the test tube being heated over the flame.

Conclusion: Answer Questions I, II, III.

Practical applications: When we go into a cellar that has a damp floor, we find that the air also is moist; if we stay long

enough, our clothing and our skin become damp. This is because the water is dissolved in the air of the cellar.

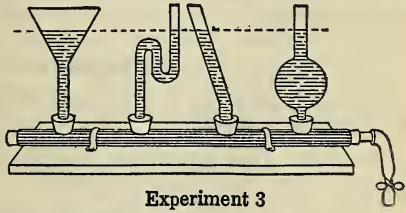
Chlorine gas is a germicide (germ killer). In large water systems the water is chlorinated (chlorine gas is dissolved in the water) in order that all germs may be killed before the water reaches the people who use it. Such a small amount of chlorine gas is used that it can kill the germs and still be harmless to people.

It is believed that certain springs dissolve minerals from the ground, and that these minerals contain healthful properties. Where water heavily laden with these substances comes to the surface in the form of springs, health resorts and sanitariums are built where people may receive treatment. Nauheim, Germany, and Saratoga Springs in New York State are examples. Sometimes the water is used for baths, and often it is taken internally.

Experiment 3

Question: How can I prove that water seeks its level?

Materials: Garden hose, board, glass tubing, rubber corks, cork borer, glass funnel.



Experiment 3

Directions: (*a*) Make a "water-level apparatus" by fastening an 18-inch length of rubber garden hose to a board. (See diagram.) Using a cork borer, bore four holes in the upper side of the hose. Bend some large and small glass tubes in various shapes. Push one end of each of the tubes you have bent through a rubber cork. The cork must be of such a size as will fit the holes you have bored in the hose. (When pushing glass tubes through rubber corks or stoppers, always wet the glass and the rubber. This will make them slide more easily. Always hold the glass tubing near

the end you are pushing in; if you hold the other end, the glass may break and you may be cut.) Place the corks containing the tubes in the four holes in the hose so that they will stand upright. Support them with clamps to keep from upsetting. One of the corks should be fitted with a funnel. Close the ends of the hose with corks. One of the corks in the end of the hose may be fitted with glass tube, rubber tube, and clamp for ease in emptying the apparatus. The finished apparatus will look like the diagram. If you lack time and materials, a similar apparatus can usually be found in the physics laboratory.

(*b*) Pour water into the funnel until it shows in all the tubes. 1. What is true about the height of the water level in each of the tubes? Add enough water to fill the tubes. 2. What is true about the water level?

Diagram: Show the water-level apparatus.

Conclusion: 1. What do you conclude about water level? 2. Do the size or shape of the tubes make any difference?

Practical application: If we know the height of the source of our water supply, we can tell how high the water will rise in our buildings.

Experiment 4

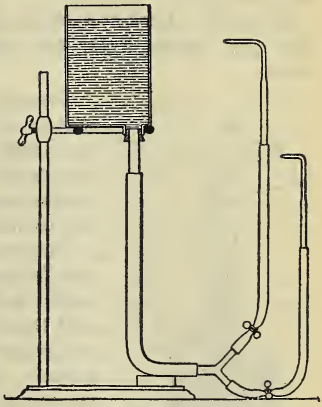
Question: How can I make and use a model of a gravity water-supply system?

Materials: Desk apparatus; tin can; glass tubing and tube clamps; short pieces of rubber tubing.

Directions: Get from a garage an empty gallon oil can with a screw top. Cut out the bottom. Put in the screw hole a rubber stopper carrying a $\frac{3}{8}$-inch glass tube 4 inches long. Turn the can bottom up and clamp it as high as possible on a ring stand. This represents our *reservoir*. (See diagram.)

Attach to the glass tube leading from the bottom of the reservoir a rubber tube long enough to reach the bottom of the ring stand. This represents our *aqueduct*.

Attach to the end of the aqueduct a glass **Y** and fasten two rubber tubes a foot long to the arms of the **Y**. These represent the *street water mains.* Put a clamp on each of these street mains so that when we wish to we can shut off the water.



Experiment 4

Attach two upright (vertical) glass tubes to the end of the street main. The upper end of these tubes is to be drawn out to a small hole. Bend the end over as shown in the diagram. These tubes represent our *house pipes* and *faucets.* Support one tube so that its open end is about an inch below the surface of the water in the reservoir. Support the other so that its open end is eight inches below the surface of the water in the reservoir. Fill the system with water and open both clamps. 1. Why does water flow from both faucets? 2. Why does the water flow from the lower faucet with more force than from the higher faucet? Raise the upper faucet until it is above the level of the water in the reservoir. 3. *Why does the water no longer flow from it?*

Diagram: Show the model that you made.

Conclusion: Answer the question. Why is it necessary to place reservoirs high above the city they supply?

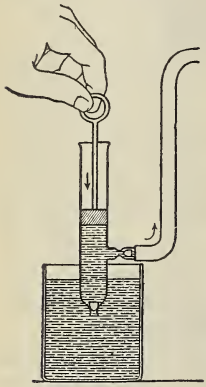
Summary: From your conclusions in Experiments **1, 2, 3,** and **4,** make eight statements about common properties of water.

Make a diagram showing the water distribution system used in your town. The engineer in charge of the water system will be willing to show you the plans when he finds that you are really interested.

Experiment 5

Question: How can I make and use a model of a pumping water system?

Materials: Desk apparatus; the gravity water-system model that you prepared for the last experiment; a model force pump.



Experiment 5

Directions: Set up the gravity water system as in the last experiment. Fill a battery jar with water and push over the delivery end of the force pump a rubber tube long enough to reach from the table to the top of the reservoir.

The water in the battery jar represents the *lake water supply.* Place the force pump in the water in the battery jar and the free end of the rubber tube in the reservoir. Pump water from the battery jar into the reservoir. From this point the experiment is the same as the one on gravity water systems. 1. Why was the pump necessary? 2. Give a brief account of the water-supply system used to supply your home with water.

Diagram: Show the model you used.

Conclusion: Answer the question.

Practical application: It is by means of one or the other of these two systems that cities supply water for domestic use and for factories.

Experiment 6

Question: How may one repair common household plumbing fixtures?

Materials: Old, leaking Fuller and compression faucets; S-trap; large and small wrenches; washers.

Directions: (*a*) Using the large wrench, open the top of the compression faucet. Unscrew the plunger to which the handle is attached. At the end of the plunger you will find a fiber

washer held in place by a small screw. (See Fig. 10a.) Take out the screw and remove the washer. Compare the used washer with a new one. 1. Why is one side of the used washer worn? 2. What effect will this have on the water-tightness of the faucet? Replace the worn washer with a new one, and reassemble the faucet.

(*b*) Open the Fuller faucet. Make sure that you understand how the rubber cone is used to shut off the water. (See Fig. 10b.) Remove the small nut that holds the rubber cone in place and take out the cone. Examine the end of the rubber cone. 1. Why is the end of the rubber worn? 2. What effect will this have on the water-tightness of the faucet? Replace the worn washer with a new one, and reassemble the faucet.

(*c*) Decomposing organic matter in the sewer causes sewer gas. Unless checked in some way this sewer gas will rise into the house through the waste pipe. To prevent this, traps are placed under house fixtures. Examine an S-trap. (See Figs. 10a, 10b, 20) Hold it vertically and pour in water until it runs freely from the lower end of the trap. Examine the trap. Observe that it remains partly full of water, and that this water forms a seal that will prevent the upward passage of gas through the trap.

Remove the plug at the bottom of the trap. Insert a wire through the hole and clean out any refuse that may be in the trap.

Diagram: Draw a cross section of both types of faucets and of a trap. (Fig. 20.)

Conclusion: Answer the questions.

Practical application: The next time that you have a leaky faucet in your home, suggest that you can repair it. Before doing the job, relieve the water pressure on the faucet either by turning off the water, or by turning on the other faucets that are at the same or a lower level.

EXPERIMENT 7

Question: How is the water supply of cities purified?

Materials: Alum; chlorine; potassium permanganate; sand.

Directions: (*a*) Prepare a quart of muddy water by shaking a half teaspoonful of clay in a quart jar of water.

(*b*) Put an inch of sand in the bottom of a fine sieve (flour sifter) and pour a pint of muddy water through it. What does the sand do?

(*c*) Put a tablespoonful of alum solution in a pint of muddy water. Shake it vigorously and allow it to settle. Does the alum carry the mud down to the bottom with it?

(*d*) Add a drop of permanganate solution to a test tube full of distilled water. Note that the pink color of the water lasts. Fill a test tube with city water and add a drop of permanganate. Notice that the color of the water quickly changes from pink to brown. This is because the water contains organic matter which is oxidized by the permanganate. This destroys the permanganate and its color disappears.

(*e*) Add a few drops of chlorine water, or a pea-sized lump of chloride of lime to a test tube full of city water. Shake vigorously. Add a drop of permanganate and notice that the pink color lasts. This shows that the chlorine used has oxidized the organic matter in the water.

(*f*) Put a half pint of distilled water in a quart fruit jar, cover it and shake vigorously so as to dissolve air in the water (aërate it). Taste the water. Notice that the flat taste of the distilled water has been improved.

Diagram: Draw a plan of a water-purification plant (Fig. 11).

Conclusion: 1. Tell what sand filters, alum, and chlorine do to the water supply of a city and why they are used. 2. Why is the city water aërated?

Practical application: This is the method used to purify the water supply of many cities.

Experiment 8

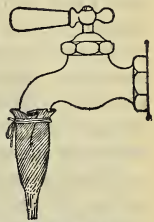
Question: Of what use is a house filter?

Materials: Piece of coarse flannel; water faucet.

Directions: (*a*) Tie a piece of flannel over the water faucet so that the flowing water will be forced through it. Turn on the water and allow it to run for ten minutes.

(*b*) From another faucet fill an 8-inch test tube with water. Fill a second 8-inch test tube with filtered water. Hold the test tubes side by side and look down through the water. Which is the clearer and why?

(*c*) Remove the flannel and examine the inside surface. Has any change taken place?



Experiment 8

Diagram: Show the filter.

Conclusion: What has the filter removed from the water? The dangerous things in water are such things as typhoid fever germs. These average 1/10,000 inch long and 1/40,000 inch thick. Do you think that the filter has made contaminated water safe to drink?

Practical application: Sand filters are used in large water plants to filter the water supply for cities. House filters do remove some small vegetable growths. Remember that these multiply with great rapidity in warm, moist places. 1. What will probably be true of their growth in the filter cloth? 2. To be safe, what care must be taken of house filters? 3. Do you think that they are of advantage in the ordinary home?

EXPERIMENT 9

Question: How can I destroy organic impurities that may be found in water?

Materials: Desk apparatus; potassium permanganate.

Directions: Prepare a weak solution of potassium permanganate. Add, using a medicine dropper, one drop of the permanganate to a test tube of distilled water. It will give the water a faint pink tint that will last for some time.

Add one drop of the permanganate to a test tube of home drinking water. The color will not be so pink, nor will the color last so long as it did in the case of the distilled water.

Add one drop of the permanganate to a test tube of stagnant, marsh or pond water. No pink color will show, and it will be necessary to add several drops before a semipermanent pink color is obtained.

Class discussion: The permanganate destroys the organic matter in the water by oxidizing it. In doing this it is itself destroyed and so its pink color disappears. The amount of organic matter present can be roughly estimated by the number of drops it is necessary to add to obtain a lasting color. Commercially, chlorine is used instead of the permanganate, but the action is the same. The writer uses the permanganate because the pink color is more easily seen than the very faint yellowish green of the chlorine.

Chlorine oxidizes the sewage, or organic matter, and thus makes the water safe for use. It is used in city water-supply systems and in swimming pools.

Diagram: None required.

Conclusion: Answer the question: Be sure to give the explanation of the action.

Practical application: See Experiment **2**.

NOTE: The water used in the swimming pools of large schools is kept safe for use by taking advantage of the facts taught in this chapter. The water is drawn from the pool after it has been used for a short time. Alum is added to coagulate the impurities and the water is filtered. Enough chlorine is then added to kill any germs present, and the clear water is pumped back into the pool. Every week a sample is sent to the laboratory of the Water Department where it is tested so as to be sure that enough chlorine has been added to kill the germs present. By taking these precautions, it is possible to use the same water over and over.

CHAPTER FOUR

HOW WATER MAKES CAVES

29. Rain water forms an acid. You will remember from last year's science work that whenever *organic* matter (or matter that contains carbon) decays, a gas called *carbon dioxide* is formed. You may not feel very well acquainted with this gas under the name of carbon dioxide, but under another name you know it very well. It is the gas that gives soda water and all bubbling drinks their pleasant tang. Carbon dioxide is *soluble* in water, and this water solution is a *weak acid.* Rain water as it falls through the air dissolves some of the carbon dioxide of the air, and the weak acid thus formed sinks into the ground. This weak acid is known as *carbonic acid.*

30. Acids dissolve marble and limestone. Marble and limestone are slightly soluble in this weak carbonic acid. Pure rain water is called *soft water.* After rain water containing carbonic acid has dissolved rock, it is called *hard water.* If this hard water is heated, the carbonic acid is broken up, the carbon dioxide is driven off, and, as there is now nothing to hold the marble in solution, it reappears as a solid.

31. Hard water and soft water. The hardness of the water is *temporary*. Such water, when softened by heating, is called *temporary hard water*.

What is organic matter?
When organic matter decays, what gas is formed?
What gas is contained in soda water?
How may rain water become charged with carbonic acid?
What is soft water?
What is temporary hard water?
How may temporary hard water be softened?

32. Hard water evaporates and leaves marble. In many parts of the country there are springs of such temporary hard water. Sometimes a kind-hearted farmer will put a glass at the spring so that travelers may refresh themselves with a drink of the cool water when they come to the spring after a hot tramp over a dusty road. The first time that one has this experience he may hesitate to drink from the glass because it looks unclean. It looks as if it were made of ground glass. This is because the temporary hard water left in the glass evaporates and leaves behind a deposit of marble.

33. Petrifactions. Objects left in the spring are also slowly covered with marble. Sometimes small boys of the neighborhood sell such things as *petrifactions*, or objects turned to stone; but, of course, they are not stone. Certain rocks, such as gypsum, are soluble even in pure soft water. Gypsum is the rock which on being heated turns into plaster of paris. This is used to make plaster figures

and casts. In this case the presence of carbonic acid in the water is not necessary.

34. Permanent hard water. Water containing these dissolved rocks (gypsum, etc.) is called *permanent hard water*. The name is a poor one, be-

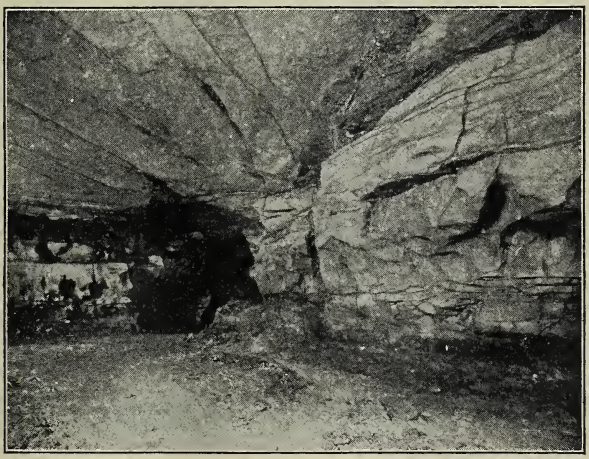


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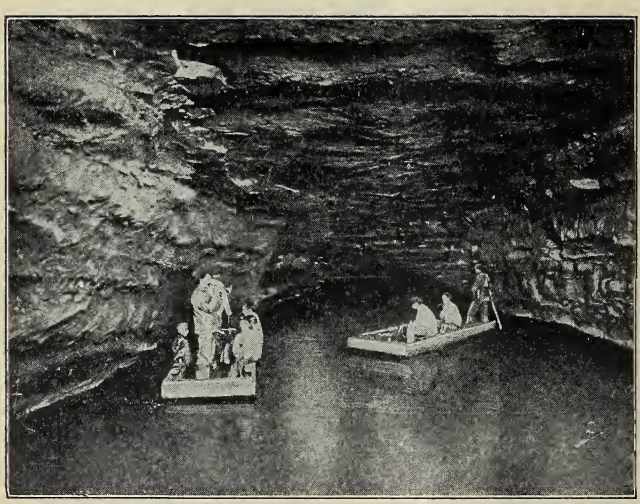
Fig. 14. This cave was formed by the action of water on the soft strata of rock

cause such water may be softened easily by chemical means, as we shall soon see. Water containing these dissolved rocks cannot be softened by heating.

What substances are contained in permanent hard water that are not found in temporary hard water?
Why is permanent hard water a poor name?
What are petrifactions?
What is plaster of paris and for what is it used?

35. What is a cave? When rock is dissolved out of the ground, a hole must, of course, be left in its place. This is a cave (Fig. 14). Since all parts of the rock are not of equal hardness, and since the



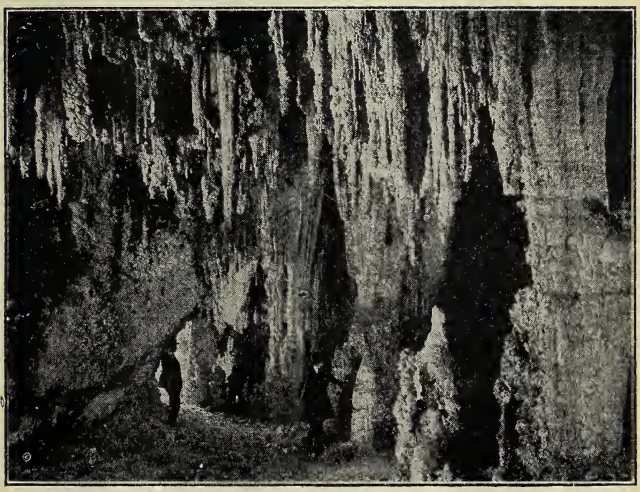
Courtesy Brown Bros.

Fig. 15. An underground river. Fish in such rivers are sometimes blind because of the lack of light

rock is usually cracked in various directions, these caves are very irregular in form.

36. Acid in water helps in making caves. A cave may be a very small cavity, just large enough for a toad to occupy, or it may be an immense cavern. There are several famous large caves in the United States which are often visited by sight-seers.

Mammoth Cave in Kentucky and Howe's Cave in New York each extend about two miles underground. The inside of a cave is a most interesting place. There is sometimes a large hall and a nar-



Courtesy Atchison, Topeka & Sante Fé Railway

Fig. 16. Stalactites and stalagmites, Carlsbad Caverns, New Mexico

row passage leading from it. Cave guides are fond of naming such places. The hall may be the Temple of Apollo and the narrow passage, Fat Man's Torment. Water is always present in a cave (Fig. 15). Far into the interior often there will be found a lake large enough to accommodate a good-sized rowboat.

37. Stalactites and stalagmites. Often after such a cave has been formed, the water that once filled the passages finds a way out and leaves the cave full of damp air caused by the evaporation of water. A rock deposit is left behind. As more water trickles into the cave, it evaporates and a fantastic curtain of rock, sometimes glistening white, sometimes stained red or yellow by iron rust, hangs from the cave ceiling. Sometimes stone icicles form. These are called *stalactites* (Fig. 16). If more water flows over the stalactite than can evaporate, some of it may drop to the floor below, where it evaporates and builds *up* a column from the floor. This is a *stalagmite* (Fig. 16). Finally stalactite and stalagmite may meet and form a column. In the winter, notice how icicles are formed and how often ice stalagmites form under them.

38. Tom Sawyer found a cave. A hunter finds a hole in the ground and, venturing in a little way, finds himself in a cave. He spreads the news, the cave passages are explored, and soon the cave has hundreds or thousands of visitors. If you have never read Tom Sawyer's cave adventure, you have a treat in store. Such caves are scattered through our country; many of them, as the Mammoth Cave in Kentucky and the Carlsbad Caverns in New Mexico, are world celebrated. Visit them when you have the opportunity. The experience will be more valuable to you than reading about them here.

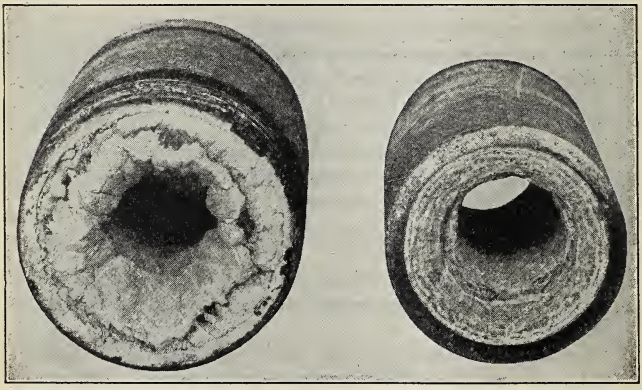
Such caves are often found in a limestone or marble rock. As the stalactites and the stalagmites are made from the dissolved rock, they must be composed of the same material as the rock itself. A simple test to prove that a stalactite is composed of limestone is to put a drop of hydrochloric acid on it. If the stalactite is limestone (calcium carbonate), it will bubble and carbon dioxide gas will be given off.

How is a cave formed?
Why are caves irregular in shape?
Why are some caves larger than others?
Why is water nearly always found in a cave?
How are stalactites formed?
How are stalagmites formed?
How are stone columns formed in caves?
How does an icicle resemble a stalactite?
Name and locate two celebrated caves.
In what kind of rocks are caves found?
Why not in other kinds?
Make a list of all the things you might see in Mammoth Cave, and give a valid reason for expecting to find them there.
Recently a mammoth cave has been opened in New Mexico. Find out all that you can about it. Compare its size, age, formation, and marvels with other well-known caves.

CHAPTER FIVE

WATER—HARD AND SOFT

39. Hard water is undesirable. Both hard and soft water are used for drinking as well as for domestic purposes, but they are not equally satisfactory.



Courtesy Permutit Company

Fig. 17. Sections of pipe showing accumulation of scale

Soft water is to be preferred. *Soft* water contains no deposits of limestone in solution, whereas *hard* water does contain such deposits. Look inside the teakettle. If you live in a region where the water is hard, you will find a deposit that coats the whole

inside of the kettle. This is really a deposit of rock that was originally dissolved in the water. Heat finds it difficult to penetrate this deposit, consequently one must use more fuel to produce heat enough to make the water boil.

40. Boiler scale. In the boilers used to make steam for use in steam engines, the extra cost of coal is a serious matter and the deposit called *boiler scale* must be frequently removed (Fig. 17). A thickness of one-sixteenth of an inch will double the amount of coal which must be used. Then, too, hard water foams in the boiler, and the water is carried along with the steam. This makes trouble in the engine.

What causes the rock deposit in your teakettle?
Why does this deposit cost money?
What is boiler scale?
Why must boiler scale be removed frequently?

41. Hard water wastes soap. In the home and in laundries there is another objection to hard water. It wastes soap. Probably your house water is at least slightly hard. If it is, shake a cake of soap around in a basin of water and notice that at first the water does not lather or foam, but, instead, a white scum forms on the water. The harder the water is, the more scum forms. The scum is an insoluble lime soap, and is waste, for, until enough soap to soften the water has been used up in this way, the soap does not do its work in making things clean

42. Soap softens water. Dissolve some soap in water so as to make a strong soap solution. Half fill a quart bottle with water, add a teaspoonful of the soap solution, and shake violently. If the water is hard, no lather will be formed, but the white scum will be seen. Keep on adding soap solution, a teaspoonful at a time, and shake, until finally a lather forms that lasts for one minute. The water is now soft, but all the soap that you have used has been turned into worse than a mere waste, for a cloth put into the bottle to be washed, would, at this point, be filled with the white, sticky scum.

Why do laundries object to using hard water?
How can you soften water with soap?
Why is this a poor method?
Why do clothes washed in hard water show a sticky deposit on them?

43. Washing soda and borax soften hard water cheaply. Soap then may be used to soften water, but this is not the best method. Clean the quart bottle and half fill it with water. Add two heaping tablespoonfuls of washing soda to a quart of water. Add enough of this solution to the bottle of water to make the water feel slippery to the touch, when you rub it between your thumb and finger. Now add a little soap solution, shake, and notice that the water lathers at once. The washing soda has softened the water. If you will use borax in the same way, you will find that it, too, softens hard

water. Both these substitutes are much cheaper than soap, and it is better to use one of them instead of wasting soap.

44. Be cautious with soda. If one is not careful, softening water with washing soda leads to a new trouble. A careless person may fill the laundry tub with water, put in the clothes, and then throw a handful of washing soda on the clothes. As the washing soda dissolves, the clothes hold it in one spot, and the strong solution will weaken the cloth. The correct way is to put as much water as is needed in the tub, make a solution of washing soda by using a weighed amount in a quart of water, and then add enough of the solution to the tub of water to make it soft. After doing this once, one will know how much washing soda to use to soften the water on wash days.

45. Simple softeners. There are other less common materials which chemists use to soften water, but washing soda and borax are within the reach of all. Both permanent and temporary hard water are softened by the use of either of these substances. For bathing, water is best softened with borax, as borax is easier on the skin than is washing soda.

In what way should one use washing soda to soften hard water?

In what way should one use borax to soften hard water?

How may clothes be injured by the use of washing soda?

The laundry work is done at home. The woman who does it has never studied science. What directions

should you give her that will enable her to soften the water that she uses?
How can you tell whether the water in your city is hard or soft?

EXPERIMENT 10

Question: How may I prepare and how may I soften temporary hard water?

Materials: Desk apparatus; dry ice or a carbon dioxide generator; limewater; soap solution; marked medicine dropper.

Directions: (*a*) Paste a narrow paper strip around a medicine dropper halfway up the tube. If you fill the dropper to this point each time you use it, you may be sure of using always the same amount of solution. This is an easy way of measuring small amounts of liquids. If you care to take the trouble, adjust the dropper so that it will always deliver just a half c. c. (cubic centimeter) of liquid, but for our purposes this is not necessary.

(*b*) Place two inches of distilled water in a test tube. Add, using your marked medicine dropper, one measure of soap solution, and then shake vigorously. Note the large amount of lather that forms and that this lather lasts for some time. Place the same amount of city water (two inches) in another test tube, add one measure of soap solution and shake vigorously. Note that a curd forms, but no lather. In a few places in our country the water is so soft that this test fails. In this case your teacher will give you an artificial hard water to test.

The lathering, or the failure to lather, of water when shaken up with soap solution is a test for hard water. The harder the water, the more soap solution must be used before a permanent lather can be obtained.

(*c*) Place a piece of dry ice (solid carbon dioxide) the size of an egg in a dry flask. Cork the flask with a stopper having a delivery tube. Lead this delivery tube to the bottom of a

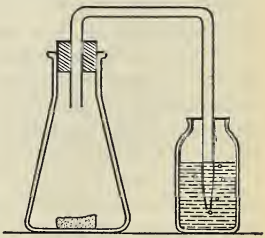
pint jar three-quarters filled with limewater. The end of the delivery tube should be drawn out to a point so that small bubbles will be formed. The dry ice will slowly vaporize (change to a gas), and the carbon dioxide produced will slowly bubble through the limewater. A carbon-dioxide generator may be used instead of the dry ice, but dry ice requires no attention and gives pure carbon dioxide.

Note that at first the limewater becomes milky. This is because the limewater is being changed into very finely divided marble (precipitated chalk). As the action continues, this marble dissolves in the carbonic acid produced by the solution of carbon dioxide in water, and a clear temporary hard water will be produced. It is not necessary to wait until all of the marble has been dissolved. Let the apparatus run overnight and in the morning filter the solution. The clear filtrate (the liquid that runs through the filter paper) is temporary hard water.

Place an inch of this temporary hard water in a test tube, add one measure of soap solution, and shake. 1. What does the fact that no lather is produced show?

Place an inch of temporary hard water in a test tube and boil the solution for a short time. Cool and add one measure of soap solution. 2. Why does the water now lather?

(*d*) Place an inch of limewater in a test tube. Blow through it, using a glass tube drawn out to a point so as to give a large number of small bubbles. The limewater first becomes milky and then clears. 1. What have you made? 2. Where does the necessary carbon dioxide come from?



Experiment 10

Diagram: Show the carbon-dioxide apparatus delivering gas to water in jar.

Conclusion: 1. Answer the question. 2. How is temporary hard water formed in nature?

Practical application: Laundries and factories often find it necessary to soften hard water before using it. In the home also it may be advisable to soften water before use.

Experiment 11

Question: How may I prepare and then soften permanent hard water?

Materials: Desk apparatus; calcium chloride; soap solution; borax and sodium carbonate solutions; marked medicine dropper.

Directions: (*a*) To one quart of distilled water add 120 grains of calcium chloride. This makes an artificial permanent hard water that is about as hard as some natural waters.

(*b*) Place one inch of your artificial permanent hard water in a test tube. Add one measure of soap solution and shake. Note that instead of a lather, a curd is formed.

Add soap solution, one measure at a time, and shake this combination until a lather is formed that lasts over the whole surface of the liquid for 30 seconds. Repeat the test, using distilled water. One measure of soap solution will make a decided lather. Repeat the test, using city water. The amount of soap solution that will have to be used before a permanent lather is produced will show the hardness of the water compared to the hardness of your artificial hard water. Record results in the table below.

(*c*) Place an inch of artificial hard water in each of two test tubes. To one tube add enough washing soda (sodium carbonate) solution to make the water alkaline to litmus paper (turn litmus a blue color). To the other tube add a half inch of borax solution. Add soap solution to both test tubes and shake. Why do the solutions in both test tubes now act like distilled water?

Table

		Measures
Number of measures of soap solution required to produce a lasting lather in	distilled water.....	.....
	city home supply water	.....
	artificial hard water....	.....

Diagram: None needed.

Conclusion: 1. How may permanent hard water be made in the laboratory? 2. How is it made in nature? 3. How may it be softened?

Practical application: Laundries often soften the water they use to avoid waste of soap in washing clothes.

EXPERIMENT 12

Question: Where does the scale that forms inside a teakettle come from?

Materials: Desk apparatus; tin pan.

Directions: Fill a tin pan with filtered city water and set it over your Bunsen burner. Heat until all of the water has evaporated. Evaporate the last few drops very slowly to avoid charring any organic matter present. Examine the bottom of the pan. A deposit will be found there. From what source did this deposit come?

Diagram: None is required.

Conclusion: 1. Answer the question. 2. What is the disadvantage of this scale? (See text, Sec. **39–40.**)

Practical application: Factory managers often find it necessary to soften hard water before use. Otherwise so much scale forms in the boilers that it interferes with their operation.

CHAPTER SIX

ACIDS, ALKALIES, AND NEUTRALS

46. Many substances contain acids. In Section 29 we referred to acids, and, as we progress in our work, we shall need to know something about acids and their opposites, alkalies.

What is more refreshing after a tennis game on a hot day than a glass of cold lemonade? The pleasant, sour taste always seems to make us think that we might enjoy a second glass. This sour taste is characteristic of many things in the kitchen. Vinegar, grapefruit, and the green apples that are such a temptation to small boys are examples. All these are sour because they contain an *acid*.

47. What is an acid? One of the tests for an acid is to taste the substance. This test is not a safe one to rely upon when testing unfamiliar substances. In any case, even though we think we know all about the substance which we are testing, we must never swallow it. In this way we shall avoid taking poisons into our body.

The next time that you cut a lemon, use an ordinary steel knife and notice that the blade is discolored. This is because acids corrode or eat metals. Put a few drops of lemon juice or vinegar on a

strip of zinc. It will bubble, showing that a gas is being given off and the metal is being corroded This is another test for an acid.

48. Acids and alkalies are opposites. Another class of substances found in the kitchen, as well as in the chemist's laboratory, are *alkalies*. These are substances that have a bitter taste. Washing soda and potash lye are examples of alkalies.

Acids and alkalies when brought together combine readily. Each acts upon the other, and, if they are mixed in proper proportions, each entirely destroys the other. That is, they *neutralize* each other. Baking powder contains an acid called *cream of tartar*, and an alkali called *baking soda*, and starch to keep the acid and alkali apart until they are dissolved. When one mixes the baking powder with cake batter, the acid and the alkali neutralize or destroy each other, and neither acid nor alkali is left in the baked cake. At the same time, a gas is produced that makes the cake light.

What is a common test for an acid?
What is the action of acids on metals?
Name three substances that contain acid.
Name two alkalies.
What happens when an acid and an alkali are mixed?
What is baking powder? Of what is it composed?
If baking powder becomes moist in the can, its usefulness is destroyed. Why?

49. Test for acid. You may astonish your friends by a simple experiment that depends on a

curious property of acids and alkalies. Boil leaves of red cabbage in water until the water is well colored. Cool the water and pour the liquid into a glass. Add a drop of vinegar and see how the bluish color changes to red. Pour a second portion of the colored water into a glass and this time add a drop of a solution of washing soda. The bluish color changes at once to green. Also try adding salt to a third portion of the cabbage water. No color change occurs, and we conclude that salt is *neutral*, or has a *neutral reaction*. *Acids* have an *acid reaction*, while *alkalies* have an *alkaline reaction*. If you will try lemons, grapefruit, or rhubarb with the colored cabbage water, you will find in every case that the water changes to red. That is, these substances all contain acids. You see then that you can use these color changes as a *test* for the presence of an acid or an alkali, because acids and alkalies always produce these same color changes. Do tomatoes contain an acid? There is no need to tell you the answer to this question for you can find out for yourself.

50. Test for alkali. In a similar way every alkali turns the red-cabbage water green. Try ammonia water or household ammonia and you will learn at once whether or not it is an alkali.

51. Litmus is better than red cabbage. Your solution of red cabbage soon spoils, and is not very sensitive to weak acids. Chemists usually use another substance called *litmus*, because it lasts longer

and is more sensitive to acids. Litmus is a blue dye made from a lichen, a fungus growth. Lichens are simple forms of vegetable life. They are usually greenish gray or brown in color, and grow in crusts or patches on trees and rocks. Litmus turns red with an acid, blue with an alkali, and remains violet when it is put into a neutral substance. You may remember these color changes by memorizing the verse written by a science pupil:

"Litmus mixed with alkali,
Turns as blue as summer sky.
Then acids turn this litmus blue
To a handsome, bright red hue."

Explain how red cabbage may be used to test for the presence of an alkali.
How would litmus be used to test for the presence of an acid?
If a potato gave no color change with either red or blue litmus, what might be concluded?
It is often desirable to test soil to see whether it is acid. How would this be done?

EXPERIMENT 13

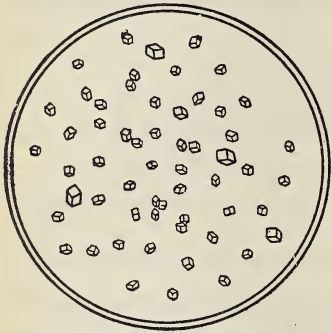
Question: How may I neutralize an acid with an alkali and prepare a salt?

Materials: Hydrochloric acid; sodium hydroxide (soda lye); litmus; evaporating dish.

Directions: (*a*) Put ten c. c. of dilute hydrochloric acid in an evaporating dish. Add a small piece of litmus paper and then sodium hydroxide solution until the litmus paper turns blue. The mixture must of course be stirred constantly. When the litmus paper turns blue, you know that you have a slight excess

of alkali. Add hydrochloric acid, drop by drop, stirring well after each addition, until the litmus turns red. The solution is now slightly acid. Add one drop of sodium hydroxide and stir. The litmus should turn violet, a shade between blue and red. One drop of either acid or alkali will now restore the original color. The solution is neutral; that is, it contains neither free acid nor alkali.

(*b*) Pour all of the neutral solutions prepared by the students into a large flask. If necessary, add a few drops of acid or alkali to make the solution exactly neutral, and filter. Pour the filtered solution into a large evaporating dish, and evaporate until the solution is saturated. Let it stand overnight. The next morning examine the solid that has formed. This is common table salt. It can be recognized by its crystalline shape (cubes) and by its taste.



Experiment 13

(*c*) Chemists call such chemical changes as this *neutralization.* The change may be expressed as an equation, hydrochloric acid + sodium hydroxide → sodium chloride (salt) + water.

Diagram: Examine crystals of common table salt and draw them.

Conclusion: How can an acid be neutralized? What do we call the result of the action of an acid on an alkali?

Practical application: Baking powder is a mixture of an acid and an alkali, such as potassium hydrogen tartrate (cream of tartar) and sodium bicarbonate (baking soda). When they are moistened, they act on each other and neutralize each other. A gas (carbon dioxide) is set free and a salt (potassium sodium tartrate) is formed. The gas (carbon dioxide) collects

as bubbles inside the cake batter and makes the cake light. Why does baking powder that has been exposed to air become worthless if left in a moist kitchen?

Gingerbread is made light in a similar way. When milk sours, an acid (lactic acid) is formed. This is what gives sour milk its acid taste. When this sour milk is mixed with baking soda (sodium bicarbonate), this same gas (carbon dioxide) is set free and this makes the gingerbread light. Think over your experiment and you will see why gingerbread is not always a success. The recipe calls for only enough baking soda to neutralize the acid that is present in ordinary sour milk. If the milk is either unusually sour or not so sour as usual, the acid and alkali will not be present in just the right proportions for exact neutralization. After baking, one or the other, either acid or alkali, will be left over and this will give the cake an unpleasant taste.

Experiment 14 (Home)

Question: What are the reactions of some common substances used in the kitchen?

Materials: Substances to be tested; litmus paper.

Directions: Using small pieces of litmus, try the reactions of such things as washing soda, baking soda, cream of tartar, tomatoes, potatoes, and fruits. Enter the results in a table such as the one below.

Table

Articles	Reactions
Tomatoes	Acid
Soap	Alkaline

Diagram: None is required.

Conclusion: Name two substances which a cook uses that contain acids, two that are neutral, one that is an alkali.

Practical application: Chemists test substances in this way to determine their reaction.

CHAPTER SEVEN

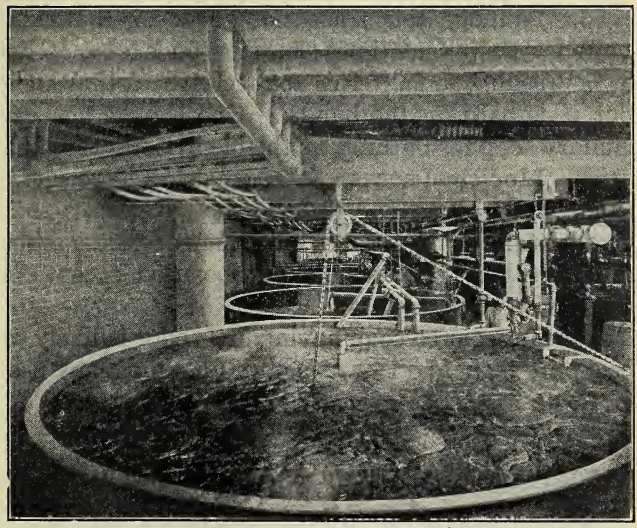
SOAP AND WATER

52. Soap is made of alkali and fat. Soap is made by mixing an oil or a fat with an alkali such as soda or potash lye, and by heating the mixture until soap forms. It makes little difference what liquid fat or oil is used. Coconut and palm oil are often used because they are cheap and clean. Sometimes pure olive oil is used. Then the product is called *castile soap*. Potash lye makes a softer soap than soda lye; otherwise their action is the same.

53. How soap is made commercially. The fat and the lye are placed in huge kettles that are heated by steam pipes. The mixture boils for hours until their combination is complete (Fig. 18). Then salt is added, and, as soap is insoluble in salt solution or brine, it rises to the top as a soft curd. This curd is dried, cut into small cakes, stamped into shape in a press, wrapped, and sold.

What is the difference between an oil and a fat?
Of what is soap composed?
What is castile soap?
How would you make soft soap?
Describe the commercial method of making soap.
In making soap, why is salt used?

54. Floating soap contains air. How many of you use a soap that floats? It is much pleasanter to use this kind of soap when taking a bath, for you do not have to spend half your time looking for it.



Courtesy Swift & Co.

Fig. 18. The kettle room in a soap factory

Have you ever wondered what makes the soap so light? The only difference between floating and non-floating soap is that while floating soap is still soft, it is beaten up, thus forcing air into it. It is light for the same reason that whipped cream is light.

55. Toilet soaps are neutral. Toilet soaps are made with great care so as to be sure that neither fat nor lye is present in the finished soap. Often perfume and a color are added to make the soap pleasant to use.

56. Laundry soaps are not good for the skin. Laundry soap sometimes contains an excess of lye or of washing soda. This soap cleans clothes well, but it is hard on the hands. One should not use laundry soap for bathing, as the lye irritates the skin.

57. Medicinal soaps. Medicinal soaps are sometimes made by adding to the soap substances that give it healing properties. Since many of these soaps are worthless, they should not be used except on the advice of a physician.

A cream-colored soap having little odor is likely to be a pure soap, and is satisfactory for almost any use.

How is a floating soap made?
What is the difference between a laundry soap and a toilet soap?
What objection is there to using a toilet soap for laundry work?
Why should a laundry soap not be used for the face?
What are medicated or medicinal soaps?

58. Avoid bright-colored and highly scented soap. Manufacturers sometimes disguise a poor soap by adding a strong perfume and a bright coloring matter. These hide the color and odor caused by the use of poor materials. Since such soaps may be impure, and since there is no advantage in their use, it is

well to avoid them. An exception to this rule is the case of some brightly colored figures put out by large soap makers to make hand washing a joy for small children.

59. Washing powders. When soft-soap curd is mixed with sodium carbonate, or washing soda, and then dried, a light powder results. This is sold as a washing powder for dishes and clothes. It is more efficient than plain soap because of the washing soda that it contains. It is, however, expensive compared to the cost of soap and washing soda. One may make this easily at home by adding washing soda to a soap jelly. A spoonful of this mixture put into the water will clean your greasy pans easily, but its action is hard on the hands.

What is a washing powder?
What is the objection to commercial washing powder?
If a small quantity of washing soda in a washing powder is a good thing, why not add a large quantity and make the powder still better?
What must be avoided when buying soap?

60. Why does soap clean things? We all use soap and we all know that it cleans. How does it do this? Let us follow the washing of a collar in a laundry and see just what happens.

61. Soiled clothes contain albuminoids. The collar is first soaked in *cool* water. This wets the dirt and dissolves certain substances that exist in the perspiration. These substances are called *albu-*

minoids. You have all boiled an egg and you know that boiling changes the white of an egg, or the albumen, from a soluble to an insoluble form. The same kind of action will take place with the dirt on a collar if it is first placed in boiling water. After soaking, soap is rubbed on the collar.

62. An emulsion. The soap emulsifies the grease; that is, the soap breaks up the fat into small particles similar to an emulsion of cod-liver oil. This emulsification is so important that it must be thoroughly understood. If we examine cream under the microscope, we shall see small oil particles floating around in a watery fluid that forms the bulk of the milk (Fig. 19). These small drops of oil are *butterfat.* When the cream is churned, these small particles are brought together, and a lump of butter results.

Fig. 19. Butter globules in cream form an emulsion

63. Make an emulsion. Fill a bottle one quarter full of water and one quarter full of oil. Shake the bottle violently. You will see that the oil and water mix and form an *emulsion,* but let the bottle stand for a time and the oil and the water will again separate. If, however, we add a small amount of gum acacia or similar material, the small drops of oil remain suspended in the water and a permanent emul-

sion results. It is in such ways that the emulsions used in medicine are made.

64. Soap emulsifies fat. Soap then emulsifies the fat in the collar. Because it is this fat that holds the dirt, the dirt is rinsed out of the collar along with the emulsion of soap and fat. Later you will study some other reasons explaining more fully why soap cleanses.

In washing soiled collars, why should the collar be first soaked in cool water?
What is an emulsion?
Name a common emulsion. Explain why you call it an emulsion.
Explain the process by which soap cleans soiled clothes.
Why does churning cream produce butter?

Experiment 15

Question: How can I make a small quantity of soap?

Materials: A fat or oil, as palm or coconut oil; sodium hydroxide; alcohol; evaporating dish; desk apparatus.

Theory: When a fat and sodium hydroxide are heated together, they combine. A soap is formed and glycerine is left. This action is slow because fats do not dissolve in water and therefore it is really impossible to mix the fat and lye. To shorten the operation we add alcohol. Since both lye and fat are soluble in alcohol, it is now possible to mix them, and the chemical change goes on rapidly. Remember that the alcohol is used in this experiment only as a solvent to hasten the chemical change. Commercially it is not used because of the expense.

Directions: (*a*) Place in a small evaporating dish 10 c. c. of sodium hydroxide solution (soda lye), 2 c. c. of any fat or oil, preferably coconut oil, and 5 c. c. of denatured alcohol.

Support the dish on your ring stand. Have ready a square of asbestos that will completely cover the evaporating dish. Heat the dish very gently, stirring all the while with a wooden splint (cigar lighter). If you heat the dish too hot, and this usually happens, the alcohol will catch fire. Remove the flame and put the asbestos over the dish. This cuts off the supply of air and the flame goes out. Wait for a minute until the dish cools and then start heating very gently.

(*b*) When the mixture has become pasty, turn off the heat, and examine the mixture. It is soap, mixed probably with an excess of lye and glycerine. Shake a little in a test tube half filled with water. It will lather, showing that it is soap. Wash your hands, using a little of the soap you have made. If you have a small cut on your hands, it will probably sting This shows that your soap has an excess of lye in it. Sometimes your hands will feel greasy after you have washed them. This shows that your soap has an excess of fat. Commercially, the quantities of fat and lye used are so adjusted that when the action is over, neither substance is left.

Diagram: None needed.

Conclusion: Answer the question.

Practical application: Soap is made commercially in this way, except that no alcohol is used.

Experiment 16

Question: How can I make a washing compound?

Materials: Washing soda; soap.

Directions: Cut up a small cake of Ivory or a similar soap into small pieces. Place the pieces of soap in a pan with a pint of water. Heat, stirring constantly to prevent burning, until the soap has dissolved. Add a tablespoonful of washing soda. Stir until you have a uniform mixture. Place this in a pint fruit jar. As it cools, it will form a thick jelly.

The next time your mother has a greasy pan to clean, place a tablespoonful of the jelly in the pan, add three times the quantity of hot water, and scrub the pan, using a brush. You

will find that the grease is quickly "cut"; that is, it will combine with the washing soda to form a soap, and the pan will be washed clean.

Diagram: None required.

Conclusion: 1. Why was the washing soda added? 2. Answer the question.

Practical application: Why not use your cleaning jelly for clothes?

Note: Washing soda is hard on your hands. Therefore do not keep your hands in this washing compound longer than necessary.

You may also clean your greasy pans by using ammonia. Ammonia is an alkali similar in its chemical action to sodium hydroxide. Add a small quantity of ammonia to the water in which you are washing the pans. The ammonia combines with some of the fat to form a soap, and assists in forming an emulsion with the remaining fat. You will find that the addition of the ammonia has lightened your work.

CHAPTER EIGHT

NECESSITY FOR GOOD PLUMBING

65. Plumbing should be properly trapped. Just as the escape of sewage into the ground outside the house may lead to contamination of the water supply and to danger from disease, so the escape of sewage into the house may lead to trouble. To prevent this, waste pipes in the house are *trapped;* that is, they are provided with a device that will allow waste to flow through them, but will not allow waste matter or odors to pass in the opposite direction. A typical trap is made by bending the pipe in the shape of the letter *S* (Fig. 20). The bend in the pipe always remains filled with water. This forms a water seal and prevents any odors from coming back into the room. Such a trap also provides a stopping place for solid materials that may fall into the waste pipe.

Fig. 20. S-trap. A, removable cap to make it possible to clean the trap; B, water standing in trap seals it against returning odors; C, sink attachment; D, waste-pipe attachment

After a while, such a trap under the kitchen sink becomes choked up with solid particles and must be cleaned. To make this possible, at the point A a

large plug is screwed into the trap. By unscrewing this plug, it is possible to clean the trap with a wire. Similar traps are provided wherever waste water runs into a large waste pipe.

66. Explanation of a toilet. To understand the construction of bathroom toilets, let us first examine Figure 21. You will see that at the back of the toilet bowl D there is a projecting piece below the level of the water in the bowl. This seals the back part of the bowl, and thereby prevents the escape of offensive sewer gas into the bathroom. To flush the bowl, a large stream of water must be provided, a stream larger than the water pipe would supply. This water comes from a tank C placed above the toilet as shown. When the valve B of the tank is lifted, a large amount of water rushes from the tank into the bowl and flushes it (rinses it out). After flushing, the inclined piece in the back of the bowl seals the bowl tightly against sewer gas coming back into the bathroom. To allow for the escape of this sewer gas, formed by the decomposition of the waste matter, a *vent pipe* is placed at the waste line

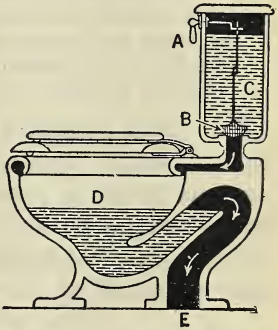


Fig. 21. Bathroom toilet. Turning the handle A raises the plug B. This allows the water in the tank C to gush into the bowl D, thus flushing its contents into the waste pipe E

in the bowl, and is carried to a level above the roof of the house so that escaping gases are carried away by the winds, and can do no harm.

Explain how a sewer trap allows water to flow through it, but prevents the escape of sewer gas into the house.
How may traps be cleaned out?
Draw a diagram of a sewer trap.
Draw a diagram of a bathroom toilet bowl, showing how the water seal prevents the escape of sewer gas, and how the bowl is flushed.
What is a vent pipe? What is its use?

67. Open plumbing is up to date and wise. The pipes of house plumbing were formerly kept out of sight as much as possible. They were hidden behind wooden partitions, or even plastered up in the walls. This was entirely wrong, because, when repairs were needed, it was almost impossible to make them without ripping the woodwork of the house to pieces. Today the piping is placed in plain view, and repairs may be easily made.

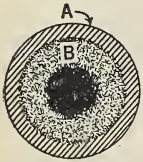


Fig. 22. A, pipe; B, deposit. Notice that the pipe is so clogged that the water pressure is much diminished

68. Requirements of good plumbing. When you build a house that you plan to live in for years, use brass piping. The first cost is somewhat greater, but it will last indefinitely without the necessity of repairs due to the clogging up of the pipes and to leaks (Fig. 22). See that the water pipes are of good size, so that you may be sure of a good

flow of water. See that all of the plumbing is placed so that it is easily accessible. Make sure that the pipes leading to the traps are short, as nearly vertical as possible, and large. Do not forget to arrange for shut-off valves so that, in case you need to renew the washer on a faucet, you can shut off the water from that faucet without cutting off the water supply from the rest of the house.

There is one more precaution that we must take in installing water pipes. We must be sure that they are so placed that the water cannot freeze. The depth to which it is necessary to bury the pipes will of course depend on the section of the country in which you live. If you live in the South, a pipe laid six inches below the surface of the soil will be safe. If you live in the Far North, a depth of four feet may be necessary. In any case, see that the pipes are sufficiently protected to make your house safe from frost and flood.

What objection is there to having plumbing sealed in the walls of a house?
What are the advantages of open plumbing?
Which is preferable, brass or lead water pipe? Why?
Which is better, long, horizontal waste pipes or short, vertical ones? Why?
Why is one shut-off valve not sufficient for a house?
Make a drawing of the plumbing in your kitchen. Label each part.

CHAPTER NINE

SEWAGE: DISPOSAL OF WASTES

69. Sewage must be kept away from drinking water. It is often a problem to know just what to do with the waste water and sewage from the house. If it is a farmhouse, standing by itself, the problem is not so hard to solve. In towns and cities where houses are close together, the matter often causes trouble. Impure waste water from the house must not be mixed with the clean water that is to be used for domestic supply. This waste water should not be allowed to remain on the surface of the ground.

70. Cesspools. The cesspool is the simplest, though not the best, solution. A cesspool is simply a large hole dug in the ground. It is often lined loosely with bricks or stones to prevent the earth from caving in and filling the hole. The waste from the house flows through a pipe into the cesspool. Bacteria grow in the organic solids and gradually make them soluble. The liquid gradually oozes away through the soil. In time, however, the interior of the cesspool becomes coated with grease from the kitchen refuse and the water no longer drains away freely. Then, the cesspool overflows and a new one must be made.

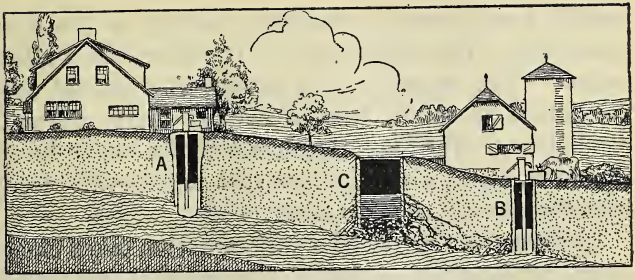


Fig. 23. The house well A will furnish pure water. The barn well B will receive drainage from cesspool C. The water will be impure and should not be used

71. Cesspools may be dangerous. Cesspools are sometimes a source of danger. If they are placed so that water drains from them into the well, the well water becomes contaminated or polluted and causes disease. They always must be so placed that the *drainage is away from the water supply* (Fig. 23).

72. Septic tanks better than cesspools. The septic tank is an improvement on the cesspool. This is an earthenware or cement box placed in the ground so that the waste drains into it (Fig. 24). Leading from the tank is a soil pipe or vitrified pipe,

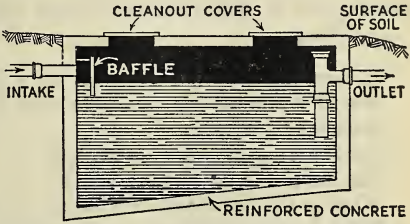


Fig. 24. A septic tank, sometimes called a sedimentation tank.

usually four inches in diameter, leading to the disposal field. The intake pipe is the same size as the outlet. The capacity of a septic tank should approximate 24 hours' flow of sewage under normal conditions. The tank depth below the water level should rarely be less than four feet, and for fair-sized installations about seven feet.

In the septic tank itself a curious action takes place which is the same as that in the cesspool, but more complete. Bacteria that have the power of making the solid matter soluble grow there. As a result of this action, much of the solid matter is dissolved and washed away. Septic tanks are very satisfactory. They require infrequent care, and last almost indefinitely.

In selecting the place for either a cesspool or a septic tank, we must be sure to choose a place where the drainage leads away from it and away from the dwelling. If we choose a low, swampy place, the waste material will not be drained away in the soil. If possible a cesspool or septic tank should be placed in a well-drained bank which slopes away from the house.

In locating either a cesspool or a septic tank, what attention should be given to the direction of water drainage? Why?
How is a septic tank constructed?
Explain how a septic tank works.
What is the advantage of a septic tank over a cesspool?
What points should be considered in the location of a septic tank or a cesspool?

CHAPTER TEN

THE CALL OF SPRING

73. Spring restlessness. When the sun's rays grow warm and the snow begins to melt, when the buds swell and the robins come back from the sunny South, when Nature is waking from her long winter sleep, we begin to feel restless. Our winter tasks grow wearisome, and possibly our teacher grows a little impatient because we are thinking of kites and skipping ropes and absent-mindedly reply that gravity causes water to run uphill.

74. Let us make a garden. The great outdoors seems to call to us. We feel that we want to dig the earth and grow things. Let us read a seed catalog. There is something fascinating about it, just as there is something fascinating about a fairy story. In it we see beautiful pictures of crisp red radishes and read of luscious melons, large and juicy. When we look over the long lists of flower seeds, each one supposed to grow and produce the beautiful flowers of our dreams, we are full of interest and energy. This is the time when boys and girls and grown-ups exclaim, "Let us make a garden."

75. What shall we plant? Long before it is possible to work out of doors, we may spend many happy

hours in planning our garden. Not only is it fun to discuss whether stringless green pod or early Valentine beans will be the best for us to buy, but we can save ourselves many later mistakes by thinking where, when, and how we shall plant these seeds.

When is a good time to plan a garden?
Why should a garden be planned in advance?
How will this early planning help one later?

76. Good gardens are carefully planned. Good gardens do not happen; they are planned, and planned with great care. First one must decide where he will plant. He must use common sense and apply science methods in deciding. Perhaps he lives on a farm and his father will provide the ground and plow it. Or he may live in a crowded city, and have only a few square feet of ground, or think that he has no ground at all. Let us see. Even on Fifth Avenue in New York there are vacant lots, and every vacant lot is a possible garden. It must be borne in mind that every garden should have sunlight, good soil, and water. A garden spot should be selected with care.

77. What to plant. What to plant depends upon how much ground is available, and what use one can make of his product. Don't try to grow potatoes in a four-by-ten-foot garden, for they will take up too much room. Don't plant a hundred-foot row of radishes when there are only three people to eat them. They may grow tired of radishes before

the crop is gone. This is a matter in which science training will help one. Plan your garden.

Plant vegetables you like and can use. Do not try to raise too difficult things the first year. Most important of all, do not plant too large a garden. Remember that fishing will be good in July and that tennis will take some of your time. Too large a garden will result in no garden at all. This year's results may be only fair, but learn from your failures, and next year's results will be better.

78. Choose wisely. If you wish to raise flowers, stick to old friends. Everyone knows and loves pansies and poppies. Flowers like these, that are known and are grown by everyone, must have a great deal to recommend them, or this would not be true. They are generally what florists call "easy doers"; that is, they are sturdy, they flower well, and do not need especial care. When you have learned how to grow the easy things, then you may try the *grandiflora rubens gigans* varieties of the catalogs.

79. Seek expert advice. A very good rule is to ask your neighbor. You probably know someone whose garden is always a success. Talk it over with him and follow his advice. Above all, be sure to keep a careful, written record of what you plant, when you plant it, and when each plant matures. This record will be a great help in planning a more successful garden next year (Fig. 25). The government issues many farmers' bulletins. These are free. Write to

Farm Garden Record. Dates are for Latitude of Kansas (Kansas Experiment Station)

Vegetable	Varieties In Order of Production	Date of Setting or Planting	Amount of Seed	Depth of Planting, Inches	Distance Between Rows, feet	Distance Apart in Row, inches (or feet)	First Picking	Last Picking	Yield to 100 Feet of Row
Beans	Stringless Green Pod	May 10	1 pt. to 50 feet	2 to 3	3	6	June 27	July 18	48 qts.
	Bush Lima	May 10	1 pt. to 50 feet	2 to 3	3	6	June 27	July 18	46 qts.
Beets	Crosby's Egyptian	April 6	1 oz. to 50 feet	½	1 to 1½	2 to 4	June 11	Sept. 11	450 lbs.
Cabbage	Premium Flat Dutch	April 24	1 oz. to 1500 plants	½	3	24	June 27	July 21	41 heads, 54 lbs.
	Early Jersey Wakefield	April 24	1 oz. to 1500 plants	½	3	24	June 27	July 21	45 heads, 52 lbs.
Carrots	Early Chantenay	April 1	1 oz. to 100 feet	½	1 to 1½	2 to 4	July 20	Nov. 1	240 lbs.
	Half Long Danvers	April 1	1 oz. to 100 feet	½	1 to 1½	3 to 5	Aug. 10	Nov. 4	120 lbs.
Celery	Giant White Pascal	July 13	1 oz. to 3000 plants	⅛	3 to 4	6	.....	Sept. 28	180 heads
	White Plume	July 13	1 oz. to 3000 plants	⅛	3 to 4	5	.....	Sept. 15	220 heads
Cucumbers	Arlington White Spine	May 8	1 oz. to 50 hills	½	4 to 6	4 to 6 ft	July 25	Sept. 20	1790, 150 lbs.
Lettuce	Black Seeded Simpson	April 12	1 oz. to 150 feet	½	1	3 to 4	May 28	.....	264 lbs.
	Improved Hanson	April 12	1 oz. to 1000 plants	½	1	3 to 4	June 1	.....	244 lbs.
Onions	Giant Gibraltar	April 12	1 oz. to 100 feet	½	1	3 to 4	Aug. 22	.....	28 lbs.
	Prizetaker	April 12	1 oz. to 100 feet	½	1	3 to 4	Aug. 22	.....	21 lbs.
Parsnips	Hollow Crown	April 12	1 oz. to 200 feet	½ to 1	1½	2 to 4	.....	Oct. 9	56 lbs.
Peas	Nott's Excelsior	April 12	1 qt. to 100 feet	3	3 to 3½	1 to 2	June 8	July 19	21 lbs.
	Gradus	April 12	1 qt. to 100 feet	3 to 4	3½	1 to 2	June 8	July 19	20 lbs.
Radishes	Early Scarlet Turnip	Mar. 22	1 oz. to 100 feet	½ to 1	1	1 to 2	May 1	May 20	3077 roots
	White Strassburg	April 10	1 oz. to 100 feet	½ to 1	1	1 to 2	May 20	June 1	2607 roots
Salsify	M. Sandwich Island	April 25	1 oz. to 70 feet	½ to 1	1½	2 to 4	.....	Sept. 4	50 lbs.
Spinach	Victoria	Mar. 25	1 oz. to 100 feet	1 to 2	1 to 1½	2	May 11	June 17	75 lbs.
Squash	Summer Crookneck	May 16	1 oz. to 20 hills, or 8	1 to 2	7 to 8	7 to 8 ft	.....	Aug. 7	13 squash, 39 lbs.
	Hubbard	June 20	to 12 seeds per hill	1 to 2	10 to 12	10 to 12 ft.	.....	Sept. 9	9 squash, 35 lbs.
Sweet Corn	Mammoth White Cory	April 20	1 qt. to 200 hills, or	2	3	2½ to 3 ft.	June 23	July 16	91 lbs.
	Stowell's Evergreen	April 20	¼ qt. to 100 feet	2	3	2½ to 3 ft.	June 23	July 16	87 lbs.
Tomatoes	Earliana	May 12	1 oz. to 1500 plants	½ to 1	4	4 ft.	July 12	Sept. 18	420 lbs.
	Stone	May 12	1 oz. to 1500 plants	½ to 1	4	4 ft.	July 12	Sept. 18	405 lbs.
	Dwarf Champion	May 12	1 oz. to 1500 plants	½ to 1	4	4 ft.	July 12	Sept. 18	217 lbs.
	Trucker's Favorite	May 12	1 oz. to 1500 plants	½ to 1	4	4 ft.	July 12	Sept. 18	230 lbs.
Turnips	Early White Milan	July 3	½ oz. to 100 feet	¼ to ½	18 in	6 in.	Aug. 15	Oct. 1	150 lbs.

Fig. 25

the Department of Agriculture at Washington, D. C., for a list of them. You will find the information in them very useful.

What are the essentials for a garden?
What would you plant in your own garden and why?
Why is it well at first to plant only familiar flowers and vegetables?
How will you keep your garden records? Why?
Where can you get good advice to aid you in gardening?

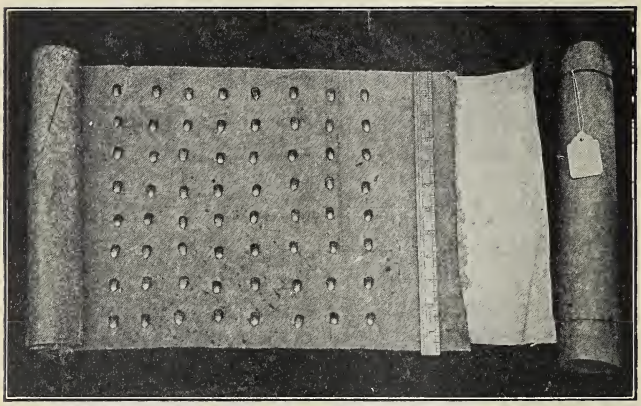
80. Make sure of good seeds. After you have taken all the trouble to make your plans, study the seed catalogs, and make your purchases. You want to make sure that the seeds will grow. You can find out all about the ability of seeds to germinate or sprout and grow by testing them indoors, long before it is time to plant them in the garden.

81. Indians tested their seeds. The early colonists in America noticed that some of the Indian tribes tested their corn seed before they planted it to see whether it would grow. It is a sensible practice. It makes sure a growth of plants in the garden, and valuable time may be saved by testing during the winter.

82. The rag-doll tester. The Indians tested their seed in earthen jars between layers of wet moss. They left the seeds in these jars until they either sprouted or rotted. We can easily use a similar and simpler plan by making a rag-doll tester. This tester is made by using a piece of muslin one

foot wide and six feet long for the doll. Hem the edges and with a soft lead pencil mark the cloth into spaces three inches square. This will give 96 squares. Number them from 1 to 96 (Fig. 26).

83. Use of the rag-doll tester. Wet and spread out the cloth with the numbered squares on it and



Courtesy Farm Journal

Fig. 26. The rag doll with the kernels in place ready to be rolled up and put into the germinating box. Usually twenty ears are tested in each doll. Ordinary muslin is used

place ten seeds of one kind on a square. You will probably not have 96 different kinds of seeds to test, so there will be plenty of spaces.

As you place the seeds on the tester, on the outside of each package from which you take the ten seeds, write the number of the square on which

you place them. For example, if you place corn seeds on space 7 of your tester, the number 7 should be written on the corn-seed package.

84. Keep careful records. After you have laid out on the various squares all the seeds you wish to test, and have recorded on their packages where they are, begin at one end and carefully roll up the tester and seeds. Be sure that you do not disturb the position of the seeds as you roll up the tester into the "rag doll." Wind twine around the tester and tie it, not too tightly, but firmly enough to keep the seeds in position.

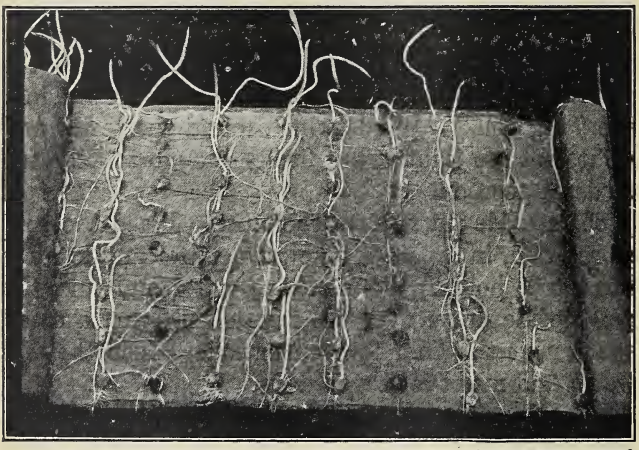
85. Seeds must have moisture. Place the roll, or rag doll, in a pail of lukewarm water and leave it for 4 to 6 hours. Pour off the water and turn the pail upside down over the rag doll, leaving a small space next the floor for ventilation. Keep the doll warm and moist for seven days.

86. Results of the test. At the end of a week you should have results. Unroll the rag doll, being careful to keep the seeds in position on their squares. If all ten of the seeds on a square have sprouted, you have very good seeds. If only one or two have responded, it is probable that you would be disappointed if you should plant them in your garden. This test is of great use to the farmer (Fig. 27).

Many seeds, especially flower seeds, take longer than seven days to germinate. If you wish to test

such seeds, consult a table of germination to find out how long you should leave the seeds in the rag doll.

The rag-doll tester may, of course, be made any size. But the disadvantage of a small tester is that it dries out quickly. One must be sure to keep it moist.



Courtesy Farm Journal

Fig. 27. The rag doll after seven days. Some diseased, some dead, and some good kernels are shown

87. Seed corn. In selecting seed corn, the farmer takes the best ears of corn from the plants that are the nearest to the ideal type of corn which he wishes to grow. These ears are dried and stored during the winter. In the spring they are tested before planting, so that the farmer knows just what percentage of germination he may expect.

Describe the construction of a rag-doll tester.
Why do you use more than one of each kind of seed?
Why use exactly ten?
Why is it necessary to keep the rag doll moist, warm, and ventilated during the test?
How long should one leave the seeds in the rag-doll tester?
Why is it sometimes necessary to use a longer period than seven days?
If nine corn seeds germinate in the rag doll, what percentage would you expect to germinate in the garden? Why?

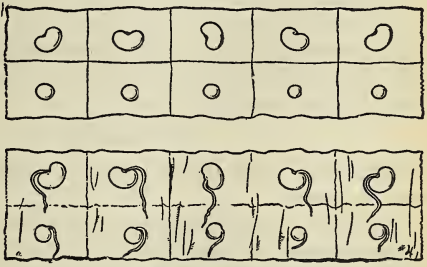
Experiment 17 (Home)

Question: What are two conditions necessary for seeds to sprout (germinate)?

Materials: Twenty beans; twenty peas; 4 pieces of muslin, four inches wide and fifteen inches long; twine.

Directions: (*a*) Prepare four small rag-doll testers, using the four pieces of muslin. (See Sec. **82**.) Each piece of muslin should be laid off in rectangles, two inches by three inches. (See diagram.) In the center of each rectangle place a bean or a pea. There should be five beans and five peas in each "doll." Roll the doll together, taking care to keep the seeds in position. Wind loosely with a piece of twine and tie to hold it together.

(*b*) Number the doll testers, 1, 2, 3, 4. Place number 1 in the ice box and keep it dry; saturate (fill) number 2 with water and place it in the



Experiment 17

ice box. Number 3 is to be kept dry in a warm (not hot) place and number 4 is to be kept moist in a warm place.

(*c*) After four days carefully unroll your testers and record the conditions in the table. Roll them up again and examine and record after six days and again after eight days. You must be sure to return each doll to its original place so that conditions for the seeds will not change through the experiment.

Diagrams: 1. Show a rag-doll tester with seeds on it at the beginning of the experiment. 2. Show number 4 at the end of the experiment.

TABLE

Testers	Conditions	Seeds Sprouted		
		After 4 Days	After 6 Days	After 8 Days
No. 1	Ice box, dry.....			
No. 2	Ice box, moist.....			
No. 3	Warm place, dry.....			
No. 4	Warm place, moist...			

Conclusion: Answer the question.

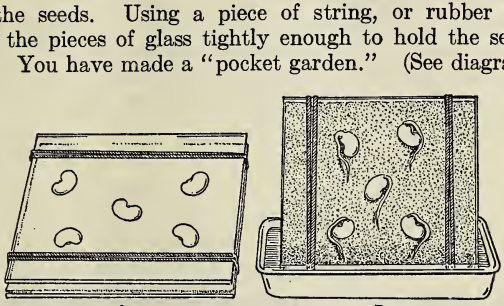
Practical application: Inexperienced people often plant their garden seeds too early in the spring. If the ground is wet and cold, seeds are apt to rot before they get enough warmth and moisture to sprout them.

EXPERIMENT 18

Question: What are the growth-direction habits of roots and of stems?

Materials: Desk apparatus; two pieces of glass four or five inches square; a piece of heavy cloth or several pieces of blotting paper the same size as the glass; seeds for sprouting.

Directions: (*a*) Lay one of the pieces of glass on your desk. Place on it the heavy cloth or blotting paper. Place several seeds of about the same thickness about an inch and a half apart on the cloth or blotter. Lay the second piece of glass over the seeds. Using a piece of string, or rubber bands, fasten the pieces of glass tightly enough to hold the seeds in place. You have made a "pocket garden." (See diagram.)



Experiment 18

(*b*) Stand the pocket garden edgewise in a pan containing about an inch of water. The water will wet the cloth, which will in turn moisten the seeds.

(*c*) After a few days you will be able to see the sprouting seeds develop their roots and stems. 1. In which direction do the roots grow? 2. In which direction do the stems grow?

(*d*) When you are sure of the direction of growth of the roots and stems, turn the pocket garden so that one of the side edges sits in the water. Watch it for several days. 1. Do the roots and stems continue to keep growing in a straight line toward the edges of the glass they originally started for? 2. What is happening?

Diagrams: 1. Pocket garden as first built. 2. The same, after seedlings show growth direction.

Conclusion: Answer the question.

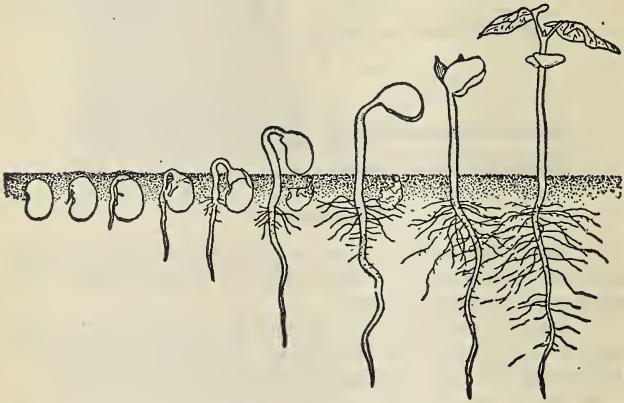
Practical application: Because of this growth-direction habit, we need pay no attention to the positions in which seeds fall when we plant them.

Experiment 19 (Home)

Question: Where do the roots, stems, and leaves of plants come from?

Materials: Desk apparatus; sawdust; peas; beans.

Directions: (*a*) Place about two inches of sawdust in a pan. After leveling the surface, place twenty-five or thirty peas or beans so that they will be about equal distances apart. Sprinkle enough sawdust over the surface to cover the seeds. Add



Experiment 19

enough water to moisten the whole mass. Set it in a warm, sunny place and keep the sawdust moist.

(*b*) After a few days you will notice that the seeds are beginning to sprout. What happens to the covering of the seeds? Make a diagram of one of the seeds when the sprouts are about one-fourth of an inch long.

(*c*) As the sprouting goes on, take out one or two of the sprouted seeds (seedlings) each day. You will soon find that a part of the sprout grows downward and another part grows upward. Make other diagrams when this begins to happen.

(*d*) As the seedling continues to grow, you will find that it is harder to pull it out of the sawdust and that more sawdust clings to it. What is forming at the lower end of the sprout?

(*e*) About this same time the seedling is lifting itself. A sprout appears above the surface. If we watch this part of the seedling for a few days, we notice that it is turning green. Which part of the plant is this?

(*f*) As the upper part of the seedling comes out of the sawdust, we notice that the thick parts of the seed are lifted out into the air. Watch these parts a few days and explain which part of the seed becomes the first leaves.

Diagrams: Show by a series of diagrams all stages of germination from the time you plant the seeds until the roots, stems, and leaves are developed.

Conclusion: Answer the question.

Practical application: The seed has everything in it for producing a young plant. There is no plant food in sawdust; therefore everything which made the plant must have been in the seed.

NOTE: Man has learned to appropriate to his own uses the food that Nature has stored up in seeds for the use of young plants. By long selection we have increased the amount of food contained in various seeds, as in the case of the bean. The original bean was a small seed. By always selecting the best of the crop for seed, man has increased both the quantity and quality of the food contained in the bean seed.

CHAPTER ELEVEN

THE NEEDS OF THE GARDEN

88. What gardens need. No matter what or where one plants, there are always certain necessary things to remember. The soil must be loosened so that air, water, and the warmth of the sun's rays may reach below the surface. Rubbish must be cleared off and the ground made smooth and level. Large gardens in the country may be plowed, but small ones in city back yards must be spaded. Water and food must be provided for the plants. They must have room to grow. All this means hard work, but one will feel repaid when he sees the results. Hard work at first makes easy work later.

89. Plant food and crop rotation. If one is replanting an old garden, he must use care. All plants take food from the ground, but all plants do not take the same foods in the same proportions. One must not plant corn in the same spot year after year, because the soil there will become exhausted of the foods that corn requires and the crops will grow smaller and smaller. Farmers *rotate their crops;* that is, they grow corn in a field one year, oats or wheat in the same field the next year, clover the third year,

and then corn the fourth year. The exact rotation used will of course vary.

What principle is involved in the rotation of crops?
Name one rotation that is sometimes used.

90. Fertilizers. In a small garden, where many plants grow close together, we avoid this exhaustion of plant food in the ground by *fertilizing;* that is, by adding plant food to the soil. Plants require many different kinds of foods, but these are all found in the soil in abundance except *nitrogen*, *phosphorus*, and *potassium*. We can replenish the supply of these by the use of a commercial or manufactured fertilizer. Each of these three foods is used by the plant for a different purpose. Nitrogen makes the leaves grow fast and crisp. A little nitrate of soda sprinkled along the lettuce rows will give nitrogen in abundance and will help the plants to produce the large tender leaves that are so good to eat. Be careful, though, not to kill the plants with kindness. A little nitrogen will help them, but a large amount will often kill them. Potassium makes the fruits and grains mature, and phosphorus is needed for seeds and roots.

Why do we use fertilizers?
What three essential elements must fertilizers contain?
What effect has each of these on plants?
Why is it not wise to use too much fertilizer?

91. Humus and the use of manure. Manure is often used as a fertilizer because it adds humus, or

Name of Vegetable	Suitable Fertilizers	Rate per Sq. Yard	When Applied
Corn Cabbage Cauliflower	Stable manure.....	10 or 12 pounds	Before plowing or digging
	or		
Eggplant Tomato	Poultry manure.....	1 pound	After plowing
	or		
Lettuce Peas Squash Celery Melons	Commercial fertilizer: nitrogen 5%, phosphoric acid 8%, potash 4%....	2 ounces	Just before planting
Potatoes Turnips Radishes Beans	Stable manure.....	10 or 12 pounds	Before plowing for previous crops
	or		
Parsnips Onions	Poultry manure.....	1 pound	
	or		
Carrots Salsify Beets	Commercial fertilizer: nitrogen 2%, phosphoric acid 8%, potash 4%....	2 ounces	Before planting
Grapes Currants Gooseberries Rhubarb	Stable manure.....	10 or 12 pounds	Between the rows in winter
	or		
Strawberries Asparagus	Poultry manure.....	1 pound	
	or		
	Commercial fertilizer: nitrogen 4%, phosphoric acid 8%, potash 4%....	2 ounces	Before cultivation in spring

Fig. 28. Vegetables and fruits arranged in groups with suitable fertilizers. Any one or all three of the fertilizers may be used.

organic matter, to the soil, and supplies the necessary fertilizing elements. A soil rich in humus acts as a sponge or blotter and does not readily dry out, does not bake and crack in the sun, and is easily cultivated. Humus makes it easy for the roots of the plants to penetrate the soil. It is especially valuable in soil that is to be used for small plants. Leaf mold, formed by the partial decay of leaves, is one source of humus. Dead leaves in our yards should be placed in piles and left to decay.

92. Crops: succession. One must arrange for a succession of crops. Radishes require only a short time to mature. After the radishes have matured, the same ground may be used for beans. Cabbages grow slowly. They may be planted early, and lettuce, a quickly maturing crop, may be planted between the cabbage rows. Before the cabbages have grown so large as to need all of the ground, the lettuce has been pulled and eaten. In such ways a succession of crops may be planned that will keep the ground of a small garden working all the time.

By studying the crop table (Fig. 29) you can select a variety of garden crops that are pleasing to you and your family.

There are other advantages in crop succession. If plants are planted close together and well cared for, their leaves will shade all the ground. This tends to keep moisture from evaporating and to discourage weeds.

DISTANCE BETWEEN ROWS

Distance between rows	Number of row	North
6″	1	Early carrots ½. Late carrots ½
6″	2	Late sweet corn
9″	3	Swiss chard
9″	4	Mid-season sweet corn. Late squash ¾. Early squash ¼
6″	5	Spinach
6″	6	Spinach
6″	7	Early sweet corn
9″	8	Endive
9″	9	Early cabbage. Lettuce between plants
6″	10	Onion seedlings or sets
6″	11	Onion seedlings
6″	12	½ cauliflower. ½ brussels sprouts. Radish between
6″	13	Onion seedlings
6″	14	Onion seedlings
6″	15	Tomatoes. Lettuce between plants
6″	16	Onion seedlings
6″	17	Onion seedlings
6″	18	½ early turnips. ½ kohl-rabi
12″	19	½ early beets. Late ½
12″	20	Salsify ½. Parsnips ½
9″	21	Spinach
9″	22	Wax beans
9″	23	Spinach
9″	24	Green beans
9″	25	Spinach
9″	26	Beans to shell
20″	27	Early peas followed by late celery
20″	28	Early peas followed by late celery
20″	29	Mid-season peas followed by late celery
20″	30	Mid-season peas followed by late celery
20″	31	Mid-season peas followed by late celery
20″	32	Late peas followed by late cabbage
20″	33	Late peas followed by late cabbage
18″	34	Early celery followed by late turnips
34″	35	Cucumbers
18″	36	Lettuce followed by winter radish
12″		

35 FEET

25 FEET — SOUTH

Fig. 29. Crop succession table

93. Plants need sunlight. Remember that plants need sunlight. If two rows of corn are planted, and a row of carrots is planted between them with the idea of saving room, the carrot crop will fail. The corn will shade the ground and the carrots will be spindling.

In what three ways is humus good for the ground?
What is meant by crop succession?
How would you arrange cabbage, radishes, and lettuce in a crop succession?
What determines the position of the tall and short plants in a garden?

94. Plant in rows. It will save time in cultivating and weeding if seeds are planted in straight rows. Since the earth travels around the sun from west to east, the rows should run from north to south. In this way, one side of each row will get the morning sun and the other side the afternoon sun.

95. Early planting. Everyone is anxious to put seeds into the ground early in the spring, but there is danger in being in too much of a hurry. As long as the soil is cold and wet, seeds will not grow, but will rot. Wait until the ground is warm before planting. There is a great difference in soils in this respect. A sandy soil can be planted long before a clay loam is ready, but the sandy soil will dry in summer while the clay loam will remain in good condition.

Why plant seeds in straight rows?
Why should the garden rows run from north to south?

What are the advantages and disadvantages of early planting?
What kind of soil can be planted the earliest? Why?

96. Cold frames. To secure the advantages of early planting without its dangers, farmers resort to *cold frames* and *hotbeds*. A cold frame is simply a box, without top or bottom, set on the ground. The sides are about twelve inches high. The back is usually somewhat higher than the front. A movable top is provided, made of glass set in a wood frame. The sun's rays pass through the glass, but once they are inside and strike the ground, the energy of the rays is changed into a form of heat that cannot get out through the glass. In this way the air inside the cold frame becomes much warmer than the outside air. In fact, the air may become too warm and cause the plants to wilt. To prevent this, it is necessary on sunny days to open the top a little so as to allow some of the heat to escape. At night the glass top is put on tightly and on cold nights an additional cover is put over the frame to keep the heat in.

Seeds may be sown in such a frame long before they may be planted out of doors. Then, when the weather becomes warm, the plants are ready for transplanting to the garden.

97. Hotbeds. We know that decay is an oxidation, and that when things oxidize, they give off heat. We take advantage of this knowledge in making *hotbeds*. A hole is dug in the ground, and over

this hole a frame is set, just as was done in making a cold frame. Then manure is placed in the hole. This is firmly pressed down, and a six-inch layer of fine mellow dirt is placed on top of the manure. As the manure ferments or oxidizes, heat is given off and the soil is warmed. At first a great deal of heat is produced. The temperature often reaches 100° F., but later the temperature subsides and remains fairly constant at about 80° F. Seeds should not be planted in the hotbed until the first hot fermentation is over. A thermometer is inserted in the soil to show the temperature. As soon as the temperature has become steady at about 80° F., the seeds are planted. They germinate and grow vigorously. By the use of such a hotbed, very early planting becomes possible. The hotbed makes it possible for us to have growing plants ready for the garden at a time when, without its use, we could only plant seeds.

How would you build a cold frame?
What is the advantage of a cold frame?
Why is it warmer inside a cold frame than outside?
Why is ventilation necessary in a cold frame?
How would you build a hotbed?
What provides the heat in a hotbed?
If you wished very early tomatoes, would you plant the seed in a cold frame or a hotbed? Why?

98. Hot caps. In California, especially, farmers resort to a curious form of cold frame. Long before it is possible to plant tomatoes and have them grow

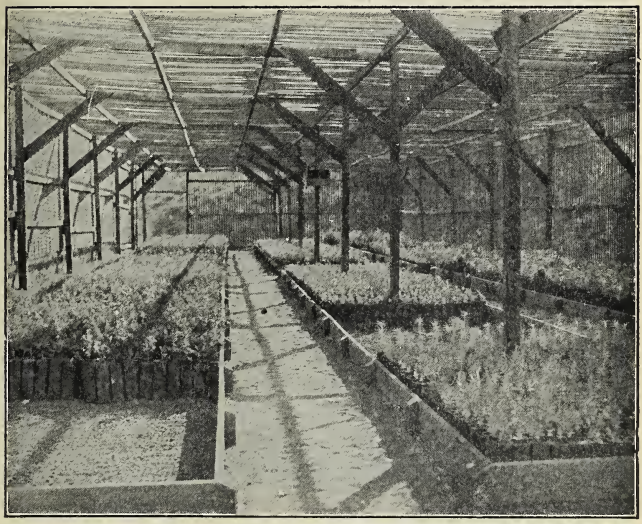
properly, the tomato plants are set in the fields, and then each plant is covered over with a cone of thin waxed paper. This gives each plant a small individual cold frame (Fig. 30), under which it makes a

Courtesy Germain Seed & Plant Co.

Fig. 30 Hot caps protect young plants from cold nights

good start, regardless of the cold nights that may come. By the time the tomato plant has grown to the top of the paper cone, the weather is warm, and the papers are taken off. It is because of such devices as this that we enjoy our early tomatoes at a reasonable price.

99. The greenhouse. We have too few small greenhouses. People who live in city apartments do not have room for them and those who live in subur-



Courtesy Los Angeles Chamber of Commerce

Fig. 31. Lath greenhouse used by Southern California florists

ban localities do not appreciate their desirability and value.

Small greenhouses, complete and ready to screw together, may be purchased for a very reasonable sum. In various seed catalogs and garden magazines, you will find plenty of suggestions and hints about constructing a greenhouse. It is possible for

any eighth-year class to design and build a small greenhouse for school use.

If you live in a locality where the winters are not severe, a small greenhouse may be constructed cheaply and it will not require heating during the winter months. In such favored localities it is possible to build shelter houses of lath, spaced an inch and a half apart. Such lath houses provide shelter from rough winds and moderate the too fierce rays of the sun (Fig. 31).

How would you make a hot cap? How do these help the early plants to grow? Where are they much used? Why are small home greenhouses uncommon in both the city and the country?
What are the advantages of a small greenhouse over a hotbed?
What is the lath greenhouse? Where can it be used and what are its advantages?

100. Plants must have water. You have often seen people sprinkling their lawns during the dry summer season. If the grass of lawns requires moisture, the vegetables in the garden, without a sod covering, require more, because the evaporation of water is greater where there is no covering to the soil.

101. Irrigation: sprinkling systems. We learned in our early science work that in the dry regions of the west, mountain streams are conveyed through aqueducts and ditches to irrigate the farming lands in the valleys.

Gardens are usually located near a water supply. Small gardens may be watered with a lawn hose. If gardening is carried on extensively, it is not practical for a person to spend the time necessary for watering the garden. In these large vegetable gardens, metal pipes connected with the water-supply system are hung on poles so that they are suspended several

Courtesy Skinner Irrigation Company

Fig. 32. Man-made rain keeps this garden in good condition

feet above the ground. These pipes have many small holes in them so that, when the water is turned on, the whole garden is watered (Fig. 32).

On lawns where overhead pipes would be unsightly, the pipes are placed under ground and the water nozzles are placed on short vertical pipes that come to the surface of the ground. Through these the lawn is sprinkled.

Many farms and gardens have small streams running near them. The water from these streams may be used in such a sprinkling system, or by irrigation, to save the crops in time of drought. These sprinkling systems enable the gardener to turn on the water where and when it is needed.

Why is more moisture required in the vegetable garden than on lawns?
How do some truck farmers water their gardens?
How does a sprinkler system work?
What are the advantages of a sprinkler system?

Experiment 20 (Home)

Question: What relation is there between growth direction of plants and sunlight?

Materials: Two similar green plants, geraniums or fuchsias; a window in the sunshine.

Directions: (*a*) Place the two plants side by side on a shelf or a table near a window, where each will receive about the same amount of sunlight. Label the left-hand plant "L" and the right-hand one "R."

(*b*) Leave "L" in one position throughout the experiment, which will extend over ten days or two weeks.

(*c*) Turn "R" each day so that a different side of it is facing the sunlight. Be sure to give both "R" and "L" the same

Experiment 20

amount of water and the same care in every way, except that "L" is never turned and "R" is turned daily. After four days you should be able to draw a conclusion about the effect of sunshine. After two weeks you should be absolutely sure.

Diagram: Show the two plants in relation to sunlight after ten days or two weeks.

Conclusion: Answer the question.

Practical application: Greenhouses are built with glass on the top and sides so that plants may receive all possible sunlight.

Experiment 21 (Home)

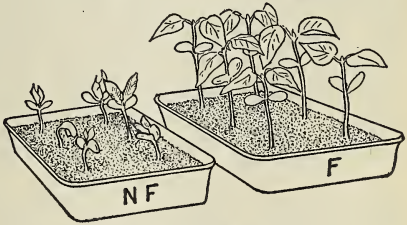
Question: How does fertilizer affect the growth of plants?

Materials: Two pans of washed sand; pea or bean seeds; commercial fertilizer.

Directions: (*a*) After the sand is washed, so that you are sure there is no organic matter in it, plant a dozen pea or bean seeds in each pan.

(*b*) Mark the left-hand one "NF" and the right-hand one "F."

(*c*) Using the fertilizer table on page 82, figure out just how much fertilizer should be used for a plot of ground the size of the "F" pan and add it to the sand in that pan. Place the pans in a warm place and give each the same care. This experiment should require two weeks.



Experiment 21

Diagram: Show the two pans and the growth of seedling in each at the end of two weeks.

Conclusion: Answer the question.

CHAPTER TWELVE

HOME GARDENS

102. Seed boxes. For the home garden, something less elaborate than a cold frame may be used. A soap box from the grocer will be satisfactory. Nail on the cover and saw the box in half to make two trays four inches high. Gardeners call such trays *flats* (Fig. 33). If there are no cracks in the bottom of the flats, bore several holes and cover them with broken flower pots or stones to prevent the dirt washing out. The cracks or holes are necessary for drainage. Put two inches of dirt in the flat and on top of this sift some fine soil. Level the dirt and sprinkle the seeds on top. Be careful not to make the common mistake of putting too many seeds in the flat. Sift a very thin layer of soil over the seeds and press it down gently. The best way to water a flat is to set it in a pan of water. This wets the soil without disturbing the seeds. The flat should be watered frequently enough to keep the soil moist, but not soaked.

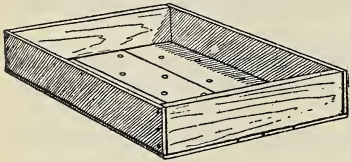


Fig. 33. A garden flat

103. Flats. Do not bury the seeds too deep. Remember that all the food the tiny seedling needs is stored up in the seed itself and that the plant cannot obtain food from the ground until it grows a root and pushes its leaves up into the air. If the seed is too deeply buried, the effort required to push its stem through the soil is too great for its strength, and the plant often dies. Do not cover the seeds with soil to a depth of more than twice their diameter. Some tiny seeds, such as the begonia, should not be covered at all, but should be merely pushed into the soil.

Tell how to build a gardener's flat.
Why are holes in the bottom of the flat necessary?
Of what use is such a flat to the home gardener?
How deep should seeds be planted?
What may occur if seeds are planted too deep?

104. Potting soil and humus. For seed boxes or flats, a special *potting soil* is often used. This is ordinary soil containing a large amount of sand and *humus*. This makes the soil crumbly, and helps it to retain water. A little leaf mold from the woods and sand mixed with ordinary loam make a good potting soil.

105. Quality or quantity? The market gardener is interested mainly in the crop that will make the most money. The home gardener is interested in the crop that is desirable for his table. Often these two things do not go together. For instance, the best watermelons are never grown for market. Their

skin is so thin and tender that it breaks easily in shipment. In selecting varieties for the home garden, remember this, and do not think that the varieties grown for market are always those which you should plant. Study seed catalogs.

106. Quality best. The home gardener has one great advantage. He raises his crop for quality, and picks it when it is at its best. If you have never been lucky enough to taste golden bantam corn that has been picked when ripe, and plunged into the pot within fifteen minutes after it left the garden, you have no idea what corn can taste like. Corn loses 50 per cent of its sugar in less than twenty-four hours from the time it is picked, and loses also that crisp freshness that makes it taste so good. The same thing is true of other vegetables and of fruits.

Your garden will pay not only because of what you learn of Nature's ways, but in the health which you will gain from outdoor exercise, and in the satisfaction that you will feel in providing your family with delicious vegetables for the table.

Do not lose interest in your flower garden because you are raising such fine vegetables for the family. Also, do not lose sight of the fact that there is more to a flower garden than raising flowers in a haphazard fashion. You must think of the height to which the plants will grow. Do not plant a pansy behind a bush that will hide it from sight. You must think also of the time when the plants will

bloom. You do not want a mass of blooms in June and then no flowers for the rest of the season. Plant for a succession of bloom just as you plant for a succession of vegetables. Finally, think how the colors of your garden will look when the flowers bloom. A magenta phlox and a crimson geranium side by side make a combination that you will not care for. Remember to grow plenty of white flowers, for the white will harmonize with any color of the rainbow.

107. Refrigeration. In order to get fruits to market in good condition, they are often picked green and shipped in refrigerator cars. The fruit colors and ripens to some extent, but is never so good as when it is picked ripe. Apricots are juicy and pink when ripe. No one who has eaten them fresh from the tree cares for the dry, yellow, tough fruit of the Eastern markets.

What is the nature of a good potting soil?
Why may a certain variety of vegetables be suitable for a market gardener and not desirable for a home gardener?
California peaches sold in Philadelphia are beautiful but sometimes tasteless. Why?

CHAPTER THIRTEEN

GARDENS AT WORK

108. House plants. The country boy or girl cannot realize how difficult it is for the city child to grow flowers in the house. Many of us live in apartments with little sunshine and with the air very dry and filled with the fumes from the gas stoves. Flowers are not easily grown under such conditions. Hardy plants grow best under the poor conditions in some houses. They should have water in plenty and all the sunshine possible. It is difficult to get even hardy plants to bloom well in city houses. Consequently it is better to rely on foliage plants and ferns to give a little touch of nature in our homes.

109. House bulbs. Next autumn, buy a few chinese lily bulbs or paper-white narcissus bulbs, and put them in a shallow dish. To keep the bulbs upright, pack pebbles around them. Add enough water to the dish so that the bulbs are one quarter covered. Then put dish and bulbs in a cool dark place in the cellar or attic. Soon roots will begin to grow and leaves will start from the top of the bulb. Later on bring the dish into the light. The leaves will grow rapidly, and soon the flower stalk with its buds will appear. These bulbs are almost

Courtesy Michell's Seed House

Fig. 34. The food that produced these beautiful blooms and luxuriant foliage was all stored in the bulbs

certain to bloom, unless the dish containing them is kept in too hot a place, or unless the roots are allowed to become dry (Fig. 34).

110. Forcing bulbs. Other bulbs, such as hyacinths, may be grown in a similar manner. After forcing them in this way, the bulbs need a two-years' growth to recover their strength. If you live in the country and have plenty of ground, plant the bulbs that have been forced and keep them for use in the garden. If you live in the city, it is not easy to do this.

Why do indoor plants grow better in the country than in the city?
Why are foliage plants and ferns often used as house plants in the city?
Why do bulbs make good house plants?
What is required for their growth?
Why will bulbs that have been forced not grow into bloom the next winter in the house?

111. Capillary attraction. The next time that you are in the laboratory, ask your teacher's permission to heat a short piece of glass tube in the middle until it is soft. Then suddenly draw your hands apart. You will find that you have drawn the tube into a thread. Small as this thread is, it has a hole through the middle. It is really a *capillary*, or hairlike, tube. Of course, you think of glass as being brittle, and so it is; but you will find that you can bend the long, thin capillary tube at right angles before it will break.

Break off a piece of the capillary, six or eight inches long, and dip one end of it into a bottle of ink. The ink will run up the tube a number of inches, owing

to what is called *capillary attraction* (Fig. 35). This capillary attraction is a very useful fact in a number of ways. It is because of capillary attraction that kerosene rises in the wick of a kerosene lamp. Blotting paper is composed of many loose fibers, and the spaces between them form capillary tubes. When a piece of blotting paper is placed on a moist ink spot, it is because of capillary attraction that some the ink is drawn into the blotting paper.

Fig. 35. Water rises higher in the smaller tube

112. Why cultivate the soil? Capillary attraction is of great importance to the farmer. As soil settles and dries, cracks appear in its surface and capillary passages form. The soil moisture is drawn through these hairlike tubes from underground where it is needed for the roots of the plants. It passes up to the surface where the sun's heat evaporates it. When this happens, the water escapes and is wasted.

It is for this reason that the farmer cultivates or stirs the soil after a rain. Cultivation breaks up the soil cracks and the tiny passages and prevents loss of water to the roots of the plants. Cultivation also kills the weeds.

What is meant by a capillary tube? Can you make one? How?

How does blotting paper absorb ink?
Hang a dry towel over the edge of a basin of water with one end dipping into the water. Water will soon drip from the lower end of the towel and the basin will soon be empty. Why?
How is capillary attraction of use to the farmer?

113. Weeds: what they are. Many a boy has had his Saturday spoiled by being asked to weed the onion bed. Just what are these weeds, where do they come from, and what harm do they do? *A weed is any wild plant that grows where it is not wanted.* The common morning-glory looks attractive when climbing over the back porch, but let it once escape into the meadow of the farmer and it becomes a pest. In California, should a patch of wild morning-glory grow in the fields, it must be pulled out at once, or the authorities will do it at the owner's expense. This is because it crowds out other plants and ruins the meadows if allowed to spread, and its seeds, blown by the winds, will make new plants to trouble others. We should never allow weeds to go to seed in the fields.

114. Weeds: where they come from. Weed a flower garden as carefully as you can and then go camping for a month. When you come back, you may find more weeds than flowers. The soil is full of weed seeds, some blown there by the winds, and some put there from the manure that has been used to fertilize the garden. A deeply buried seed may remain dormant for years, but some day you may

stir the soil, bring it to the surface, and another weed appears that must be destroyed.

One reason why everyone should be careful not to let weeds grow is that the wind carries the seeds to a neighbor. The careless farmer who lets a colony of weeds grow in his fields not only damages himself, but causes damage to his neighbors. He is in this respect not a good citizen.

115. Weeds: the harm they do. Weeds are harmful in many ways. They are always strong, sturdy plants and, if allowed to do so, will often crowd out the more tender cultivated plants. They are the bullies of the fields, and no one likes bullies. They take much water and food from the soil. This makes it harder for the cultivated plants to grow. They do not look well. Pull them up. If everyone would get rid of weeds before they ripen and form seed, work for the rest of the year would be much easier, and the following year the crop of weeds would be much diminished.

Doctors tell us of one more harmful thing that weeds do. When the flowers of weeds are ripe, a powder called *pollen* forms on the *stamens* of the flower. Look at a lily or some other large flower. You will see in the center of the flower a number of projecting, slender stalks. These are the stamens. If the flower is ripe, each stamen will be covered at the end with a yellow powder called pollen. It is this yellow dust that fertilizes the flower and enables

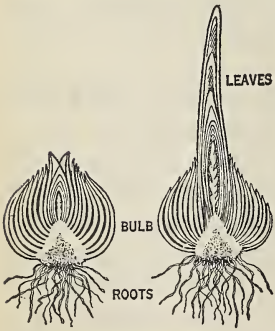
it to form seed. The pollen of the ragweed is blamed by the doctors for much of the hay fever that causes so much misery. It is said that it is the pollen floating in the air that causes the trouble. The pollen of other plants may also cause it, but the ragweed is the worst offender. This is another reason why you should not permit ragweed in your garden.

What is a weed? What harm do weeds do?
Why can the same plant be both a weed and a flower?
How are weeds spread?
What do weeds take from the ground?
Why are weeds sometimes called "soil robbers"?
What is the advantage of pulling weeds before they ripen and form seed?

Experiment 22 (Home)

Question: Why does nature provide thick scales or leaves in a bulb?

Materials: Two hyacinth bulbs or chinese lily bulbs; a saucer containing gravel or small stones; a knife.



Experiment 22

Directions: (*a*) Cut one bulb in half lengthwise.

(*b*) Study the inside of the cut bulb and notice the following: A central part which is a tiny plant; the thick scales which surround the young plant and the small roots on the bottom.

Note: A bulb is a shortened, thickened stem. The leaves of the stem are thickened and placed close together.

(*c*) Place the uncut bulb roots down in the saucer filled with gravel.

(*d*) Pour enough water in the dish just to cover the stones, and set the saucer in a dark place for a week.

(*e*) At the end of a week, examine the bulb you have set away. 1. Have the roots begun to grow?

(*f*) If so, set the saucer on the window sill for daily observation. 1. As the plant inside the bulb shoots up or grows, what happens to the thickness of the scales or layers of the bulb? Is the bulb as firm as formerly?

Diagram: 1. A drawing showing the cut section of the bulb. Label the roots, shortened stem, leaves or scales, and the tiny plant. 2. A drawing of the bulb after it has begun to grow, showing how the new plant grows out of it.

Conclusion: The young plant could get no nourishment from the moistened stones. Answer the question.

Practical application: Man has learned that plants provide food in various ways for their young to use the following year. By growing large numbers of bulbs, we can greatly increase the number of these plants. The onion is a bulb from which man appropriates nature's plant food to his own use.

Experiment 23

Question: Why does a blotter absorb a drop of ink?

Materials: Desk apparatus; blotter; magnifying glass; towel; glass tubing; tumbler of colored water.

Directions: (*a*) Find in the laboratory a short waste piece of glass tubing. Heat the middle of this over a Bunsen burner until the glass is soft. Pull the ends of the tubing apart, and you will draw it out into a fine thread. Break this into several

Capillary tubes

Blotter magnified

Experiment 23

pieces and put one end of each piece into the tumbler of colored water. Notice that the water rises in each tube and that it rises to a different height in each. Look at the small tubes and notice the varying bore (inside diameter) of each. Such small tubes are called *capillary tubes.* Does the water rise higher in the tube having the smaller or larger bore?

(*b*) Look through the magnifying glass at a piece of blotting paper. You will see that it is made up of countless small fibers arranged so that they crisscross in all directions, and that there are small spaces between them. Blotting paper is then really a mass of capillary tubes formed from the air spaces between the fibers. In the same way look at a piece of smooth writing paper and notice the absence of any space between the fibers.

Put a drop of ink or colored water on a glass plate. Dip a piece of blotting paper and a piece of writing paper into the ink. Explain why the ink is drawn up into the blotting paper but not into the writing paper.

Diagram: Show how the colored water is drawn up in the capillary glass tubes to various heights, and how blotting paper looks under the magnifying glass.

Conclusion: Answer the question.

Practical application: A careless hotel guest left a damp towel with one end in a basin of water and the other end hanging over the side of the table on which the basin stood. What happened and why? If you are not sure of the answer to this, try it at home, but be sure to put a pail under the hanging end of the towel. 1. Why does the wick of a lamp draw kerosene up from the body of the lamp to the flame? When a lamp wick is old, it becomes filled with gum from the kerosene. It then does not work well. Why? 2. Why can you not write with ink on blotting paper? 3. Of what use is capillarity to the farmer? After a bath we dry ourselves with towels. Which dries us better, a rough, loosely woven towel or a smooth, tightly woven towel? Why?

CHAPTER FOURTEEN

GARDEN ENEMIES

116. We have planned well. We have planned and planted a garden. We have arranged to have in it those things which we care for most, such as fruits, flowers, and vegetables. We are prepared to cultivate the soil and to kill the weeds that will attempt to monopolize the plant food on which garden plants must depend for their living.

Perhaps we have gone so far as to anticipate a dry season and have intimated to father that we will need some extra garden hose. We are going to give the garden plenty of water in order to keep it growing.

117. Environment counts. The success or failure of our garden will depend very largely on the conditions under which it has to live and what we can do to make these conditions most favorable for the life of our plants. We do not intend to leave the garden to shift for itself. We want to help it to win out in such a manner as to allow it to produce for us food and flowers in abundance.

118. Nature is friendly. Nature provides the necessary conditions which a plant needs. If Nature provided living conditions for nothing but garden plants, the garden would get along very nicely. In

that case our problem would consist mainly of carrying out the plans we have already talked about. Cultivation, warmth, moisture, and air would be our chief concern.

119. Some friends of Nature are garden enemies. We are planting our garden largely because we are interested in having the flowers for our pleasure and the vegetables for our food. Unfortunately, we are not the only ones in the world who are interested in having the benefit of the garden. Millions of insects — bugs, grubs, caterpillars, plant lice, and beetles — are roving the earth and the air searching for food. What better place could there be for this hungry army to settle down and partake of a feast than in our well-cared-for garden?

120. They come in numbers; they colonize. We do not notice their coming. They are such small and insignificant individuals that if we saw only one of them, it would be natural to say, "What harm can one little bug do? He must be a stingy fellow who would begrudge a little potato beetle a few bites from a potato leaf."

If they came singly, and lived singly, the problem would not be difficult. But this is not the case. There is no such thing as dealing with an individual bug in such a way as to protect our garden.

121. Insects are pests. The insects which we call pests (and for good reason) seem to come with a plan of invasion and destruction well mapped out.

First, a few *adult*, or grown-up, bugs or butterflies or beetles appear. They find the tiny, tender leaves just appearing above the ground. Each bug picks out the plant in which it is most interested. It then proceeds to arrange for a family which is to grow up and feed on the leaves of that particular plant.

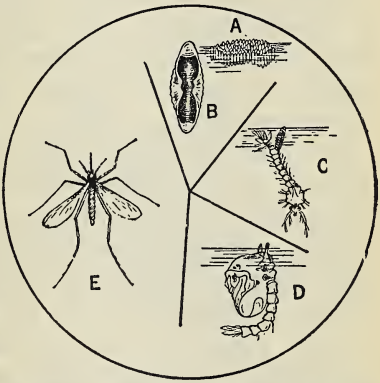


Fig. 36. Life history of the mosquito. A, mass of eggs on surface of water; B, single egg magnified; C, larva, commonly known as a wriggler; D, pupa; E, adult

122. Stages of an insect's life. In order that we may understand the problem a little more fully, we must know something about the way in which insects develop.

123. Egg. The adult appears and lays myriads of eggs on the underside of the young and tender leaves of the garden plants. In a short time, the eggs hatch and, in most cases, the young insect that comes out of the egg is a grub, a maggot, or a caterpillar. It is called a *larva* (Fig. 36).

124. Larvæ. These young insects, called the *larvæ*, are always very hungry. If they are not inter-

fered with, they will devour the very vitals of the plant. Some of them strip the leaves, thus depriving the plant of its breathing organs and its means of making starch for the rest of the plant. Others dig into the ground and eat into the roots, thus robbing the plant of the food that the roots gather for it. Still others lay their eggs on fruit and on the bark of fruit trees, where the larvæ may find plenty of fruit to eat and destroy during their development.

All insects do not pass through the larval stage. A few of them resemble the parent when they hatch out of the egg, but are much smaller, of course. Whether an insect goes through a larval stage or not, does not seem to affect its appetite. All insects are voracious eaters when they are young.

125. Pupæ. The larvæ, after they have eaten and grown to a certain point, wind themselves up in cocoons. This is the *pupa* stage of their lives. In the pupa stage they are *dormant* or quiet and sleeping. Often the insect sleeps the whole winter through in the pupa stage.

126. Adult. When conditions are right, the pupa wakens and a full-fledged adult insect appears. It looks just like the one that laid the eggs on the leaf. This adult insect immediately goes about the business of laying eggs.

Why are insects in a garden objectionable?
What are the stages in an insect's life?

127. The cabbage butterfly. Take, for example, the cabbage butterfly (Fig. 37). In the spring, we find the cocoons fastened to stone piles, trees, or buildings, as the case may be. If we watch one of these cocoons, we shall find that a full-grown butterfly comes out of it. If we are able to follow this little cabbage butterfly as it flits about, we shall find that on the very day it comes out of its long sleep and development in the cocoon, it proceeds to a cabbage field and lays a hundred or more eggs on a young cabbage leaf.

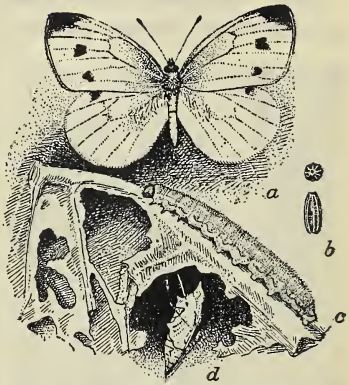


Fig. 37. The cabbage butterfly. a, female butterfly; b, eggs; c, larva; d, chrysalis

In a few days these eggs hatch and the larvæ, which we call *cabbage worms,* set to work to eat their fill of cabbage leaves.

We could cope with this one butterfly perhaps, but, as we look over our cabbage patch, we see dozens, and possibly hundreds, of these little flitting butterflies darting here and there. When we know that each female butterfly in this colorful group is depositing large numbers of eggs and that each egg will

produce a hungry caterpillar, we doubt if there will be enough cabbage to go around.

The cabbage butterfly may be taken as an example of the development of most insects.

128. European corn borer. Another insect that attacks our crops is the European corn borer (Fig. 38). This insect is a foreigner. It was imported unintentionally into the United States in broom corn from Italy and Hungary in 1909 and 1910. The larva of this insect attacks not only corn, but also beans, beets, potatoes, and many other vegetables in our gardens.

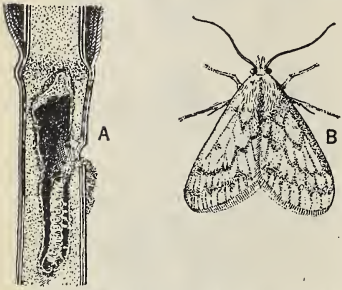


Fig. 38. European corn borer. A, section of cornstalk showing larva eating therein; B, adult female corn-borer moth

The European corn borer, while it is living as a caterpillar, tunnels into the corn plant and builds its cocoon there in the early summer. In about three weeks the adult moth emerges or comes out from her cocoon and lays from 350 to 1000 eggs on the corn plant. These eggs hatch in a week. The young borers immediately gnaw their way back into the cornstalks, where they eat and pupate. In less than two months another generation of adults appears. Thus two broods of corn borers appear in

one summer. The larvæ of the second generation pupate in the cornstalks and spend the winter there.

There are a number of different insects that bore into the bodies of plants. Their life habits are similar to those of the European corn borer. All are harmful to plants, but the European variety is probably the worst one. The United States Department of Agriculture considers the destruction caused by this borer so serious that it has prohibited the importation from foreign countries of plants which may contain cocoons or pupæ of this insect.

Courtesy U. S. Bureau of Entomology

Fig. 39. The Mediterranean fruit fly

129. The biters: Mediterranean fruit fly. The insects that we have just discussed are members of a large group of garden pests. Each plant seems to have some insect which feeds upon it. The young larvæ of the butterflies and moths are biters. That is, they have jaws with which they can bite and chew the leaves of the plants. A few other insects that attack plants by biting are beetles, tent caterpillars, cankerworms, locusts, and grasshoppers.

The Mediterranean fruit fly, which was discovered in this country April 7, 1929, belongs to the biting group. This insect attacks all fruits grown in the United States except the pineapple and the watermelon. Congress has appropriated $4,250,000 for fighting this pest which the Department of Agriculture calls "probably the worst of all fruit pests" (Fig. 39).

130. The suckers. Not all insects actually eat up the plants. Another method of attack is employed by insects that have no biting jaws. Instead of jaws, they have a piercing tube for a mouth. This tube is driven into the stem, leaf, or root of a plant and used as a sucking tube for obtaining the life-giving juices of the plant.

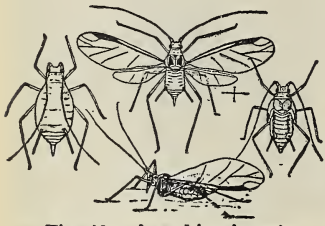


Fig. 40. A sucking insect

You may have permitted a mosquito to insert its sucking tube through your skin and fill itself with your blood. It is in this manner that sucking insects obtain the sap of plants (Fig. 40).

Among the sucking insects are the plant lice, called *aphides*, the San José scale, and the citrus scale. The scale insects manufacture or secrete and give out coverings for their bodies that seem to protect them from the weather and their natural enemies.

Name an injurious biting insect; a sucking insect. Give the life history of the cabbage butterfly; of the European corn borer; of the Mediterranean fruit fly.

Experiment 24

Question: (*a*) How do aphides or plant lice take nourishment from plants?

(*b*) How do great numbers of aphides affect the plant?

Materials: Growing plants of cabbage, turnips, lettuce, or house plant infested with aphides; magnifying glass.

Directions: (*a*) Examine one of the aphides under the magnifier. You will find that it does not move about but is intent on procuring food.

(*b*) Is this true of all the plant lice on the plant you have?

(*c*) Look closely at the front (anterior) end. How does the aphis get its food?

(*d*) Can one do great damage to a plant?

(*e*) Count the number of aphides on the plant when you begin the experiment and count them again a week later. Are there more or less of them?

(*f*) As time goes on, how does the condition of the plant change?

Diagram: None needed.

Conclusion: Answer the questions.

Practical application: Aphides or plant lice are very common. They possess slender sucking tubes with which they puncture the soft tissues of plants and suck out the sap. They reproduce rapidly and because of their great numbers destroy the health and beauty of plants. They can usually be exterminated by spraying the plant with nicotine solution.

Experiment 25 (Home)

Question: Why should we swat the fly?

Materials: Dinner plate; screen dome to fit closely inside the rim of the plate; a piece of decaying meat or fish about two inches square; five or six house flies.

Directions: (*a*) Place the meat on the plate and place the screen dome over it. This will act as a cage for the flies if the edge fits tightly all around.

(*b*) Capture some live flies and place them with the decaying food in the cage you have prepared, and set it away where it will not become offensive, but where you can observe it daily.

(*c*) Flies begin to lay eggs when they are about 10 days old. It takes about 8 hours for the eggs to hatch into maggots. The maggots finish their growth in 6 or 7 days, then they burrow into manure or other decayed material and pupate. They exist as pupæ from which they come forth as adult flies in about 3 days.

(*d*) It has been estimated that a fly lays 150 eggs in a batch and she usually lives to lay 6 batches. A pair of flies beginning to produce eggs May 1 would be the cause of flies as shown in the following table. Half the young flies are supposed to be females.

May 10	152
May 20	302
May 30	11,702
June 10	34,302
June 20	911,952
June 30	6,484,700

Diagram: None needed.

Conclusion: After proving the arithmetic in the above table, answer the question.

Practical application: Flies may carry the germs of tuberculosis, spinal meningitis, smallpox, leprosy, typhoid fever, and many other diseases. They also may carry the eggs of tapeworms, hookworm, and a number of other parasitic worms. Only about two persons die from the bites of poisonous snakes in the United States each year; about a hundred from the bites of mad dogs; but nearly 100,000 people die annually from diseases carried by flies.

Experiment 26 (Class)

Question: How does the locust or grasshopper destroy plant life?

Materials: Live grasshoppers; live plant; wire screen dome cover; magnifying glass.

Directions: (*a*) Place the grasshoppers or locusts on the plant (grass will serve very well) and using the screen dome, make a cage which will confine the grasshopper and the plant for observation.

Experiment 26

(*b*) How large are your grasshoppers? When they are first hatched, they have no wings; only shoulder pads. They eat and grow and molt, or burst out of their skins, several times during the summer. Each molting shows more development of wings until the adult has wings longer than the body. What age are your grasshoppers, young, middle age, or adult?

(*c*) Watch the grasshopper; does he remain in one place a long time as does the aphis?

(*d*) Notice his mouth; is it composed of a sucking tube such as the aphis has? Look for two jaws which open and close in a different direction from yours and mine. What is the condition of the leaf after the grasshopper has eaten for one day? How does the grasshopper obtain food?

Diagram: Holding the grasshopper in your hand under the magnifier, make a sketch of the biting edge of his hard jaws.

Conclusion: Answer the question.

Practical application: The grasshopper is used as an example of a biting or chewing insect enemy of plants. The Rocky Mountain locust is the one that causes such great damage in the United States. Encyclopedias give vivid descriptions of how these insects move through a country in such numbers as to devour every living green thing in their path.

CHAPTER FIFTEEN

GARDEN FRIENDS

131. Friend "ladybug." The score against the insect world is very bad. We should be unappreciative indeed if we did not give credit to a few insects that are friends of man and gardens. They wage continual warfare against harmful insects.

The little lady beetle, commonly called *ladybug*, does not feed on plants (Fig. 41). Her food consists of eggs and larvæ of other insects. So valuable are these insects to man that farmers in fruit regions have imported them for the express purpose of killing off the biting and sucking insects which destroy the fruit.

Fig. 41. The ladybug, magnified 6 diameters

132. Tachina flies. All insects lay their eggs in places that will supply food for the larvæ when they hatch. Tachina flies do not care for vegetable food. The eggs of this insect are laid on the larvæ of other insects. When the tachina-fly grubs hatch, they burrow into the body of the insect on which the eggs were laid. Here they find

food to their liking as well as a good place to pupate. This process is life to the tachina fly, but death to the unfortunate insect that has been compelled to act as host and banquet (Fig. 42).

133. Snakes, toads, and skunks. The fact that insects breed in such large numbers gives their natural enemies a busy life. Some of our garden friends would not be classed as close and intimate friends of man. Snakes do not attract us, but they help us by consuming a large number of enemies of the garden. Toads live exclusively on a diet of insects. The dreaded skunk, if undisturbed, proves himself an efficient friend by devouring multitudes of insects and their larvæ.

Fig. 42. A tachina fly

134. Bird friends. The greatest friends the garden has are the birds. Because of their active lives, they have to eat continually. A large part of their food consists of the very pests which we term enemies of the garden.

135. Bluebird. We grow flowers for their beauty. What can add to the charm and beauty of a garden more than the stylish and aristocratic bluebird as he flits about among the plants and shrubs? His satisfied chirp seems to tell us that he is working very hard to rid our garden of bugs and other insects. Three fourths of this bird's food comes from this source. He eats wild berries for his dessert.

136. Wren. The scolding wren is driven almost to distraction gathering insects for her noisy brood. Where does she find the food to quiet them even temporarily? Watch her dart away. Off to the garden she goes. Here she gathers the food from plants and trees and shrubs. Her food and the food of her babies is almost entirely insects.

137. Phœbe. We must not forget the modest phœbe as she sits demurely on a twig or a telephone wire. If you encourage her, she will tell you her name, "Phœ-be, Phœ-be." Suddenly she seems to think of something that ought to be attended to at once, and off she goes. She has spied a swarm of insects flying about. She darts into the middle of the mass. She seems to turn and flutter for a moment. Then she flies back to her perch to enjoy her catch. She loves insect meals. It is her habit to catch her victims "on the wing." That is why she is called a flycatcher.

138. Robin. The robin lives on caterpillars, worms, grasshoppers, and wild fruit. Does he tell you when it is going to rain? People in the country say that he has a different song before a rainstorm. He is a delightful companion. One of the writers of this book once had a tame robin that would alight on his desk and try to take his pencil away. When worms were being dug preparatory to a fishing trip, Robin was always on hand to get his share of the worms before they were deposited in the bait box.

139. Study the birds. We cannot take the space to write all that we would like to write about the birds. We hope, however, that enough has been said to prompt you to learn more about them from one of the many fine bird books. Birds are our friends and we should make every effort to keep them contented and happy in our gardens. Providing food and homes for them is a profitable investment.

140. Bird houses. A little study in a good bird book or a garden manual will tell us all we need to know to build the kinds of bird houses these insect fighters enjoy. You will find that each bird has a particular hobby about its dwelling place. Some live in the shade and some love to have their homes in the open; some nest near the ground and others live in high places. They are particular about the size and the location of the entrance, and the shape of the nest on the inside. When we are acquainted with the tastes of our bird friends, many happy and profitable hours may be enjoyed in cultivating that acquaintance.

141. Natural insect enemies must have help. It is unfortunate, but interesting, that the efforts of the friendly insects, such as the ladybug and the tachina fly, added to the combined forces of the toads, the snakes, the skunks, and the birds, are not enough to keep down the armies of insect pests that are bent on the destruction of our gardens. Science must come to the rescue.

142. We must do our part. Man has discovered ways in which he can destroy the insects, their eggs, and their larvæ, without doing harm to the plants on which they live. He does this by spraying certain

Fig. 43. This man is using a spray pump to get rid of the harmful insects

poisonous chemical substances on the plants at the proper time.

Name three animals that are garden friends.
Name three birds that are garden friends.
Why should we encourage birds to nest near our gardens?

143. Common insecticides. The most common insect poisons, known as *insecticides*, are paris green,

zinc arsenite, lead arsenate, calcium arsenate, and nicotine. These poisons may be used as a powder, but the most satisfactory way is to dilute them in water and put them on with a spray pump (Fig. 43).

144. Caution. Insecticides may be bought at drug stores and at garden supply stores. We must remember that they are poisons, and that the directions on the outside of the package for dilution, application, and storage must be followed absolutely.

145. Summary. To sum up briefly, we can say that harmful insects, mostly in their larval forms, are the garden's worst enemies. There are friendly insects, toads, snakes, skunks, and birds waging war against these pests. All these forces of nature are not sufficient to hold the ravages of the hungry insect army in check. Science comes to the rescue with insecticides, which, if carefully applied at the right time and in the right manner, will insure the life and beauty of our gardens.

Experiment 27

Question: How is the toad a great help to the gardener and the farmer?

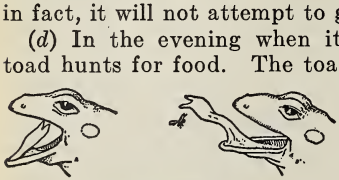
Materials: A toad in natural surroundings.

Directions: (*a*) First, find the toad. This will be a comparatively easy matter for boys and girls who live in the country or small towns. For city dwellers, it will be difficult and perhaps impossible. In the daytime, the toad does not move about very much. It spends its time in shadowy places where it will not be conspicuous to its enemies, the snakes, and some birds.

(*b*) Having found your toad, get acquainted with it. Pick it up gently, examine its jaws. You will find that it has no teeth. Do not take it away; leave it where you found it. Do not frighten it.

(*c*) At first the toad may play dead, but after a few days you will find that it will become accustomed to you; in fact, it will not attempt to get away when you visit it.

(*d*) In the evening when its enemies are asleep, the toad hunts for food. The toad is a good example of the patient hunter. It moves about quietly and waits for prey to come within range.



Experiment 27

(*e*) After you have watched the toad dart its tongue out unerringly for bugs and other insects, explain how they are captured.

(*f*) After a few days, you can study the feeding habits more closely. When the toad becomes friendly with you, offer it a fly or a young grasshopper on the end of a toothpick. What happens? The toad's tongue is covered with a sticky substance and is attached to the front of its lower jaw. How does it operate in capturing its food?

(*g*) You will find that the toad eats insects only. Has it a good appetite?

Diagram: Make two sketches showing the toad's tongue (1) in repose, (2) in action.

Conclusion: Answer the question.

Practical application: Toads are much abused and little appreciated. They do not cause warts; they do not rain down; they do not eat their tails and they are never found alive in solid rock. They devour large numbers of harmful insects and are indeed true friends of the plants. In Europe, toads are regularly sold to be turned loose in gardens for the protection they give the plants and vegetables against harmful insects.

Experiment 28 (Field Trip)

Question: What are some of the habits of the earthworm that make it valuable to the farmer?

Materials: Earthworm burrows in a field or a lawn.

Directions: At first it will be difficult to recognize the home of the earthworm.

(*a*) Notice that the mouth of the burrow is guarded by small stones or by leaves which often have been dragged some distance.

(*b*) Frequently you will find that leaves have been drawn into the burrow. The earthworm shows considerable intelligence by always drawing in the narrow end of a leaf first. The reason for drawing leaves into the burrow is probably to prevent entrance of enemies, to keep the burrow warm, to prevent moisture from evaporating, to have a food supply near by, and to enable the worm to lie near the mouth of the burrow without being seen.

(*c*) A heavy rainfall will usually bring the earthworm to the surface. Watch a robin or other bird in the grass searching for the earthworm. Can the earthworm cling to its burrow? Describe the efforts of the bird in capturing the worm.

(*d*) Look carefully around the mouth of the burrow for castings that have been expelled by the worm. When castings are found, the burrow is not usually guarded by leaves and stones.

(*e*) The burrow is made partly by the awl-like front end pushing its way through the earth and partly by actually swallowing the earth—eating its way through the soil.

(*f*) "Night walkers" are large earthworms that have the habit of stretching themselves on the surface of the ground at night. Go into the garden in the evening and capture a few for a fishing trip. Describe your experience in getting the night walker.

(*g*) It has been reckoned that about 50,000 worms live in one acre of farm land. What effect would this have in providing air and moisture for the roots of plants?

(*h*) It has also been estimated that each worm ejects each year $1\frac{1}{4}$ pounds of earth it has swallowed. The composition of worm castings is much the same as that of humus. How many tons of earth could 50,000 worms move in a year? What effect would this have on fertility of the soil?

Diagram: None needed.

Conclusion: Answer the question.

Practical application: The earthworm is a conspicuous example of the workings of Nature which benefit mankind without attracting attention. In our study of science we are taught to be alert and keen; to observe things. An investigation of the earthworm and its habits will convince us of the importance of asking questions of Nature.

Experiment 29 (Home)

Question: How may I build an efficient feeding table for birds?

Materials: Two boards approximately two feet long, six inches wide, and one inch thick; some boards eighteen inches long and one-half inch thick; a strip of glass about eighteen inches long and five inches wide; some shingle nails; six short strips of lath or lattice wood; two strips of galvanized wire mesh one foot wide and eighteen inches long with one-half inch meshes; a hammer; a saw; a pole seven feet long, that cats cannot climb; twenty-four upholsterers' staples.

Directions: Make a box, using the inch boards to form the sides, the half-inch boards for the top and bottom, and the strip of glass for one end. The other end is to be left open.

(*a*) The glass end of the box should be eighteen inches wide, while the opposite open end should be two feet wide. The glass is held in place by the strips of lath.

(*b*) The top which forms the shelter and the bottom which forms the feeding table should cover only eighteen inches on

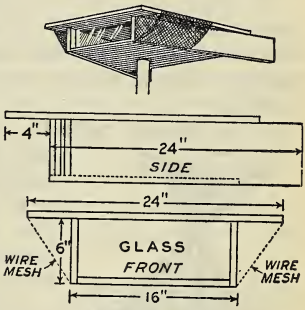
the sides; that is, the inch-board sides should project six inches beyond the roof and the floor as wings.

(*c*) The roof should have a four-inch overhang on the glass end.

(*d*) Fasten the pieces of wire mesh on the sides of the table so that one edge is secure to the roof edge and the other edge is fastened to the end of the floor boards.

(*e*) The best way to mount this shelf is to fasten it to the top of an iron pipe in such a manner that it can swing with the wind. Since the glass end is narrower and the sides project, the open end should be pointed away from the wind so that the food is not blown away, and so that the birds will be sheltered behind the glass while they feed.

(*f*) The wire mesh is for a suet cage. Many birds are fond of suet and are known as suet eaters. If the suet cage is made in this way, the suet is kept against the wire where the birds can reach it.



Experiment 29

Diagram: The directions here given are very general. Perhaps you can improve them. Draw a diagram of the feeding shelf which you build.

Conclusion: Answer the question with reference to the feeding table that you build.

Practical Application: Feeding the birds is very important in the winter. It is desirable to keep them about us. Comfortable feeding tables and bathing places as well as safe nesting places, will insure their presence.

Experiment 30 (Home)

Question: How may I build a wigwam bird bath?

Materials: Four rustic sticks, with the bark still on, approximately four feet long and one and a half inch in diameter; a

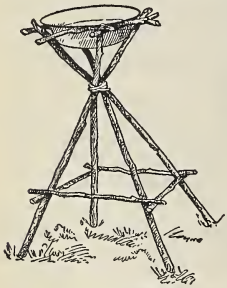
number of twigs approximately one-half inch thick and two feet long; a washbasin; some wire sixpenny nails; a hammer; a piece of twine; some leaf-green paint.

Directions: (*a*) Tie the four long sticks together with twine about one foot from one end.

(*b*) Spread the long ends of the sticks wigwam fashion. This will leave the short ends sticking up so that they will support the washbasin.

(*c*) After you are sure that you have obtained the proper pitch or slant of all four legs of your bird bath both above and below the point where they cross, tie the string tightly so that it will not slip, and nail the four sticks securely together.

(*d*) In order to make the support of the bird bath sturdy, nail the short half-inch twigs to the legs, about two feet from the ground, so as to connect them and act as braces. You can now pick up the wigwam support and move it about without fear of its collapsing.



Experiment 30

(*e*) You now have a four-legged support. The ends of the sticks which project above the point of union extend in four different directions.

(*f*) Set the washbasin so that it will rest on the four prongs.

(*g*) You will find that it topples rather easily. In order to make the washbasin sit solidly, nail some half-inch twigs around the top of the wigwam so that they will support the rim of the washbasin.

(*h*) Paint the outside of the basin with the leaf-green paint, and place it on the support. Put in about two inches of clear water. You have made a wigwam bird bath that the birds will enjoy.

Diagram: None needed.

Conclusion: Answer the question.

Practical Application: Birds are our friends. They not only destroy harmful insects, but they also add to the beauty of life. Even if there be a stream or lake or pond in the garden, the birds will take to the shallow, still water of the bird bath. They are frightened by running water and by deep water, but are very happy to play in this simple arrangement that can be built in half an hour.

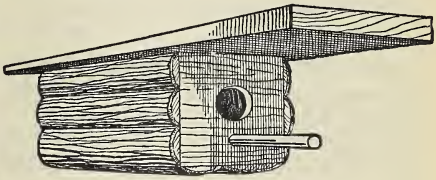
EXPERIMENT 31

Question: How can I attract the bluebirds to my garden?

Materials: A box about $4\frac{1}{2}$ inches square and 7 inches long on the inside; some pieces of slab wood or bark; a $1\frac{1}{2}$-inch end bit; a $\frac{1}{2}$-inch end bit; a $\frac{1}{2}$-inch stick about 4 inches long.

Directions: (*a*) Cover the box with bark or slab wood to make it inconspicuous. If you cannot get the bark or slab wood, stain the box a grayish brown.

(*b*) Place a slanting board on top for a roof. This board should be about 14 inches long so that it will project well over the front when placed the long way of the box. (See diagram).



Experiment 31

(*c*) In the center of one end (the front) of the box bore a hole $1\frac{1}{2}$ inches in diameter for an entrance.

(*d*) Bore a $\frac{1}{2}$-inch hole $\frac{3}{4}$ inch below the edge of the entrance.

(*e*) Fasten the 4-inch stick into this hole to serve as a perch.

(*f*) Hang the house you have made on a slender limb or on a pole that is too frail for a cat to climb, not more than ten nor less than seven feet from the ground. You must use great care that the size of the entrance hole is just right.

Diagram: Show the bird house that you have built.

Conclusion: Answer the question.

Practical application: Since we know of the appetite of bluebirds for harmful insects, it is wise to encourage them to live among our plants.

EXPERIMENT 32

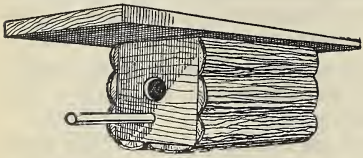
Question: How can I attract the wrens to my garden?

Materials: Same as Experiment **31**, except that box does not need to be so large; 4 inches square and 6 inches long; 1-inch bit.

Directions: (*a*) Follow the directions for a bluebird house, only make a 1-inch entrance hole instead of a $1\frac{1}{2}$-inch hole. This will allow the wren to enter but will keep out other larger birds.

(*b*) Hang the wren house in a tree where cats cannot reach it.

Diagram: Show your wren house.



Experiment 32

Conclusion: Answer the question.

Practical application: Same as Experiment **31.**

NOTE: We are able, in this book, to discuss only a few of our most common birds. It is the hope of the authors that through these brief investigations you will become interested in a more complete study of our feathered friends. Wonderfully illustrated bird books are available in every public library. Some of the interesting questions that we might ask ourselves are: How can we attract robins, blue jays, kingbirds, and catbirds to our gardens? Why do we not find wood thrushes around dwellings? What is the history of the English starling in this country? Why should we not encourage the visits of the English sparrow?

CHAPTER SIXTEEN

WASTE AND FOOD

146. Early man lived from day to day. During early times in man's life on the earth, the question of food must have been a constant problem. The killing of some large animal would supply food for the tribe for a few days, but the next day's hunt might fail, and soon famine might stare them in the face. Even today such tribes as the Eskimos, who are almost entirely dependent upon hunting for food, often suffer great hardships when game is not to be found. Read Kipling's "Quiquern" for an interesting account of such an event.

147. Man has learned to increase and save food. Soon man found that it was possible to plant and cultivate food crops and to store up and preserve food in such forms that it would be available in times of need. Drying, pickling, and salting were early ways of preserving food, and these same methods are in use today. One modern method, refrigeration, was not available to early people, unless they happened to live in a country which was always cold.

Why did early man often go hungry?
Name three early methods of preserving food.
Why was refrigeration not generally used to preserve food in early times?

148. Air, moisture, and heat cause foods to spoil. Before we can understand how foods are preserved, we must know why they spoil. Let us recall certain facts which we all know. Canned corn remains unspoiled so long as the can is not opened, but when the can is opened, the corn soon spoils. This seems to show that *something from the air causes decay.* We know that dry corn keeps, while moist corn spoils. This seems to show that *moisture causes spoiling.* We know that keeping milk in the refrigerator retards its spoiling. On a hot day, milk kept on the kitchen table soon sours. This looks as if *a moderate heat causes it to sour.*

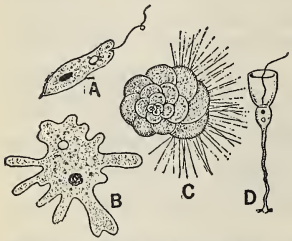


Fig. 44. Types of protozoa, or one-celled animals. A, Euglena, boat form with lash (an animal containing green coloring matter like the plants); B, Amœba, which moves by changing its shape; C, Foraminifera, having bony skeleton; D, Mastigophora, collared form

149. The simplest forms of life: protozoa and bacteria. Heat, air, and moisture alone will not necessarily spoil foods. Tiny plants and animals which live and thrive in warm, moist air are the cause of decay. *Protozoa are one-celled animals* that have neither arms nor legs; neither ears nor eyes; neither stomach nor heart (Fig. 44). They often look like tiny masses of lemon jelly. Many of them are so small that it takes thousands of them side by side

to make an inch. Most of them can be seen only under powerful microscopes, while others are large enough to be just visible to the eye. They are the simplest form of animal life. Many of them live in water. They also live in the air, in soil, in animals, and in man. They often cause serious diseases, such as smallpox.

Name three conditions that aid the spoilage of food.
What are protozoa?
Name a disease caused by protozoa.

150. Bacteria. *Bacteria are one-celled plants* similar in many ways to the protozoa (Fig. 45). Bac-

A B C

Fig. 45. Forms of bacteria. A, pus; B, lockjaw; C, cholera

teria are found everywhere. The air, the soil, water, our foods, all are homes for these bacteria. Many of them are useful to us, but some called *pathogenic bacteria* cause disease when they grow in our bodies. It would be wrong to say that all bacteria and protozoa are harmful. Many of them are continually performing friendly acts for mankind. Decay is

caused by bacteria. Just think what would happen if nothing ever decayed. The world would indeed be a rubbish heap.

151. Microbes and germs. In this chapter we are discussing food and the conserving and saving of it. Our brief discussion of these small organisms is only in that connection. Bacteria and protozoa are so much alike that the names *microbes* and *germs* are often used for both. In fact, it is often difficult to tell to which class any given form belongs. In both, food is taken into the cell by absorption. In both, oxygen passes in and carbon dioxide passes out through the cell wall. They have no nervous system, no mind as we understand it, yet they are alive, reproduce, and move from place to place.

To what two classes of living things do bacteria and protozoa belong?
How do they resemble each other?
What good do they do in the world?
What harm do they do in the world?
What do newspapers generally call both of them?

152. Growing protozoa. In order to convince ourselves that these little plants and animals actually exist, let us try a simple experiment in which we encourage them to grow and multiply.

Put a handful of hay into a quart fruit jar and fill the jar with water from a small pond. Let the jar stand for several days in a warm place. You will notice in a few hours that the water grows cloudy, and if you can examine a drop under a good micro-

scope, you may see that the water is full of life. The hay furnishes food for these growing organisms, or protozoa, and they multiply amazingly. These tiny animals cause decay of the hay, as is shown by the disagreeable odor and the scum that forms on top of the water. These cells are *paramecia* (singular, *paramecium*). Ask your teacher to let you look at a drop of the hay water which contains them. You will be astonished at their shape, size, and activity. If you will examine the water day by day, you will see many new kinds of one-celled organisms appearing.

How can we make protozoa grow?
What are paramecia?
What causes the decay of the hay?

Courtesy U. S. Bureau of Entomology

Fig. 46. Colonies of bacteria which have been transplanted by a fly's feet

153. Colonies of bacteria. Prepare a nutrient jelly and put some in Petri dishes. (See Experiment 33.) Both gelatin and dish should be heated very hot to *steritize* them; that is, to kill any microbes present. Expose the gelatin on two of these dishes to the air for a few minutes. Any bacteria floating in the air will fall upon the gelatin, stick there, feed

upon the food provided for them, and grow. A single bacterium is too small to be seen with the naked eye. When, however, thousands of them grow upon one spot and make a blotch on the gelatin, they form a *colony* that is visible (Fig. 46).

154. Germs do not thrive in the cold. After exposure to the air, put one of these Petri dishes in the refrigerator and the other in a warm place. After a few days examine both. In the first dish the gelatin will remain practically clear. In the second dish, colonies of bacteria will appear as spots or blotches. This result teaches us that *the air contains bacteria*, that *warmth aids the growth of bacteria*, and that *cold retards their growth.*

155. Milk and water contain bacteria. Add a drop of milk to the surface of the sterile gelatin in one Petri dish. Place a drop of drinking water on the surface of another. Put these two dishes away in a warm place for several days. When you examine these dishes later, you will find the surface of the gelatin dotted with colonies of bacteria. You will also notice that the dish to which the milk was added contains many more colonies of bacteria than the dish to which the drinking water was added. This experiment shows you that both *milk and water contain bacteria*, and that milk contains the larger number. Since the bacteria grow so well upon the moist surface of the gelatin, we may also conclude that *moisture aids the growth of bacteria.* The details

of all these tests will be found in Experiments 33 and 34.

What does "sterilize" mean?
How do you sterilize gelatin?
Why do you expose the Petri dishes to the air?
What is a colony of bacteria?
Why did you keep the Petri dishes used in the tests above in a warm place instead of in the refrigerator?
Name three conditions that are favorable to the growth of bacteria.

EXPERIMENT 33

Question: Where may I find bacteria?

Materials: Three Petri dishes; gelatin; bouillon cube.

Directions: (*a*) 1. Wash the Petri dishes and covers clean. 2. In a pint of water dissolve the bouillon cube and a tablespoonful of gelatin. 3. Boil this mixture three different times, twenty minutes each time, in a flask loosely stoppered with a plug of cotton. This is a *culture medium.* 4. After the culture medium has been properly sterilized, pour enough of it into each Petri dish to cover the bottom about one-eighth of an inch thick. 5. Place the covers on the Petri dishes and again sterilize in an oven twenty minutes three different times. 6. Leave the Petri dishes containing the sterilized culture medium in the oven until they are cool and the medium has set in a jellylike consistency.

(*b*) The cultures which are now translucent may be exposed.

1. Allow a house fly to walk over the surface of the culture medium in the Petri dish Number 1, and replace the cover.

2. Touch culture in Number 2 with the tip of your lead pencil and replace the cover.

3. Leave Number 3 open a few minutes in the classroom and replace the cover.

(*c*) You have now exposed the three cultures in three different ways. If there were bacteria present on the feet of the

house fly, on your pencil point, or in the air of the classroom, they will grow and multiply in the culture medium.

(*d*) Keep the three Petri dish cultures at room temperature for a few days. What has happened to the clear culture medium in each case? The spots or blotches are made out of millions of bacteria. The spots are called colonies of bacteria.

A B

Experiment 33

Diagram: Make a drawing of a Petri dish culture (A) before it is exposed, (B) after bacteria colonies have formed.

Conclusion: Answer the question.

Practical application: The culture medium contains food on which the bacteria thrive. If these bacteria were disease germs and got into our bodies, they would multiply in this same fashion. By the use of Petri dish cultures, disease germs are grown and studied by scientists who are always searching for methods of exterminating them.

Experiment 34 (Class)

Question: What is the size and appearance of one-celled animals?

Materials: Compound microscope; glass slides and cover glasses; water containing one-celled animals (protozoa); medicine dropper.

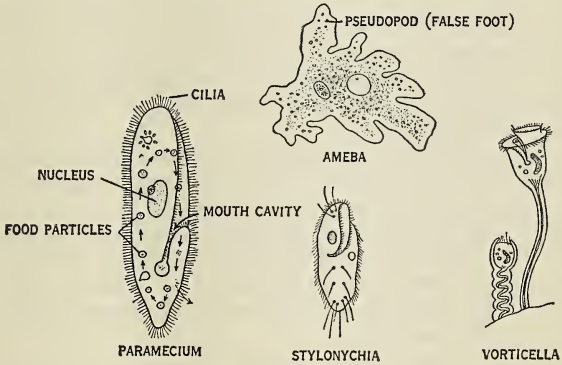
Note: The water containing these tiny animals can be obtained by placing a handful of hay in a jar of water and allowing it to stand in a warm place for a few days, or by procuring a jar of stagnant water containing some dead leaves from the edge of a pond or lake.

Note: It is not advisable to allow pupils to manipulate a compound microscope. This should be done by the teacher. After the slide is prepared, the microscope focused, and after

the teacher has explained what to look for, the pupils should take turns in observing the specimen.

Directions: (*a*) Ask your teacher what power of magnification the microscope has. If the microscope is magnifying 50 times, everything you see through it will look 50 times as large as it really is.

(*b*) The drop of stagnant water on the glass slide may contain any of the following animals: paramecium, stylonychia,



Experiment 35

amœba, or vorticella. Using the following descriptions, try to identify them and learn of their size and appearance.

Caution: Probably the most conspicuous thing you will discover will be a circular object with a very dark ring around it. This is not an animal; it is an air bubble.

(*c*) The paramecium is slipper shaped, about 5 times as long as it is wide. The toe of the slipper is more pointed than the heel. It moves with a smooth motion with the blunt end forward. There is a groove in one side near the blunt end; this serves as a mouth. Around the edges are fine colorless projections which are vibrating all the time; these are *cilia;* they

are used for locomotion and for causing currents of water which work food into the mouth groove.

(*d*) Stylonychia resembles paramecium somewhat, although it is shorter and wider. It has cilia around its body, as does paramecium. It also has longer cilia, for the most part near either end. It moves with a jerky motion.

(*e*) Vorticella is a bell-shaped organism. It is usually attached by the "handle" of the bell, although it can detach itself at will. You will discover the cilia around the rim of the bell. Notice that the handle of the bell is not always straight; it can be drawn together to resemble a corkscrew. If you watch vorticella a few seconds, you will see the stalk or bell handle coil up and uncoil as it pushes the body of the animal about in search of food.

(*f*) Amœba has no general shape. It is continually changing its form as it flows about. It has no cilia or organs. The part that flows foremost is called a pseudopod or false foot. When it comes in contact with small particles in the water, which it can use as food, the body flows around them and envelops them, then the foot becomes a mouth and a stomach. Any part of the amœba may become the foot. It only depends on which part flows out in advance.

Diagram: Make a simple sketch of one of the one-celled animals you have seen under the microscope and tell how many times it is magnified.

Conclusion: Answer the question fully.

Practical application: The one-celled animals (protozoa) you have studied are closely related to bacteria. By studying these animals, we can learn something of the habits of other one-celled organisms, including disease germs.

CHAPTER SEVENTEEN

WAR AGAINST GERMS

156. Preserve food by removing the causes of decay. The spoiling of food is due to the growth of germs or bacteria. To preserve our food, we must prevent this growth. From your experiments you will see that this can be done by: (1) killing the bacteria present and then covering the food to prevent other bacteria falling on it; (2) drying the food, since this removes the moisture necessary for the growth of bacteria; (3) adding materials, such as salt, in which bacteria cannot grow; (4) keeping the food cold either by refrigeration or cold storage, since bacteria cannot grow in the cold.

All these methods are used; the choice of the method depends on the nature of the food. For example: tomatoes are canned, peas are dried, meat is salted, and eggs are kept in cold storage.

Name four ways in which food may be preserved.
Upon what does the method we employ depend?

157. Canning foods. The grocery store with its rows of canned foods is so familiar to us that it is hard to realize that canned food is a recent thing, yet the first canning factory in this country was

Courtesy National Canners Association

Fig. 47. A modern canning factory. From the peeling tables, the tomatoes are placed on belts and carried to the canning department. Here they are hand-packed into cans

opened no longer ago than about 1820 (Fig. 47). You yourself may easily can some of the products from your garden. If you have more peas than you can use during the summer, shell them, put them in glass fruit jars, fill each jar with water, add a little salt, put on a rubber ring, and cover. Boil until all the bacteria have been killed and the peas cooked. Then snap the clamp to hold the cover on tightly. The peas will keep almost indefinitely, because you have killed all of the bacteria present, and no new ones can get in.

158. Why canned goods spoil. Sometimes the contents of a jar of canned food will spoil. This must be either because the rubber ring is old and does not fit well, or because the glass cover has cracked, or because the heat did not penetrate to the center of the jar and kill all the bacteria, or for some similar reason. In all these cases, living bacteria have come into contact with the food. Knowing the cause of spoilage, you may avoid it in the future.

159. Avoid "swellers." Occasionally the food put up in tin cans spoils for one of these reasons. The ends of such cans are pushed out by the gases that are formed by the decaying of the food. Such cans are called "swellers"; their contents should never be used.

What, in general, are the steps to be followed in canning food?
Why do canned foods keep?
Why do canned foods sometimes spoil?
What causes a "sweller"?
Why are peas boiled in the can before clamping on the cover?

160. Food preservation by drying. Canning is expensive and the product takes up a good deal of space. Vegetables and fruits are often dried to avoid this expense and to save room. Apricots, for example, are cut open, the pits taken out, and the halves placed skin side down on trays (Fig. 48). Sometimes these apricots are dried in the sun and

sometimes the trays containing them are put in warm ovens to dry.

161. Drying vegetables. Vegetables are dried in a similar manner. Such *dehydrated vegetables* take

Fig. 48. Apricots drying beside the orchard, Riverside, California

up little room and are often carried by explorers for that reason. Beef and fish, too, are dried, and even dried eggs may be found in the market.

What are the advantages of dehydrated vegetables?
How are dried apricots prepared?
How could you prepare dried apples at home?

CHAPTER EIGHTEEN

FOOD PRESERVATION

162. Artificial ice. Our great-grandfathers regarded ice in the summer as a great luxury, while we think of it as a necessity. This change is due to the fact that ice is now largely artificial and can be easily

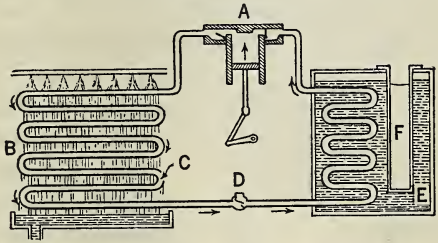


Fig. 49. An ammonia ice plant. A, compressor; B, water spraying over pipes called the condenser; C, liquid ammonia in pipes; D, expansion valve; E, brine; F, tank of water being frozen

manufactured in ice factories or plants or at home. The method used will be understood from the next paragraph.

Liquids that evaporate easily are called *volatile.* Put a few drops of a volatile liquid, such as alcohol or ether, on your hand and wave your hand in the air. The alcohol will quickly evaporate and your

hand will feel cold. *It takes heat to evaporate liquids*, and this heat is taken from your hand. If ammonia, a very volatile liquid, is surrounded by a brine, which is a solution of salt in water, and then the ammonia is evaporated, so much heat is taken from the brine that it is cooled below the freezing point of water, or as cold as ice. On placing cans of water in this cold brine, the water in the cans is frozen and artificial ice is obtained. The ammonia gas is then cooled by water, compressed to a liquid, and used over again. As the ammonia is not lost, the process is cheap (Fig. 49). Other volatile liquids might be used instead of ammonia, but this would increase the cost.

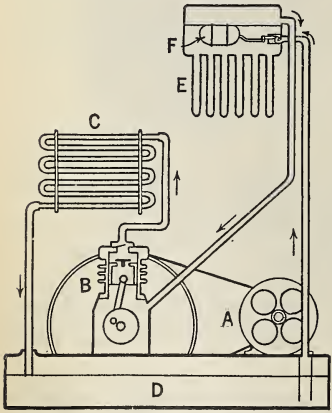


Fig. 50. Electric refrigerator. A, electric motor; B, compressor; C, condenser; D, storage tank; E, cooling unit; F, float valve controlling pressure

163. Electric refrigerators. The *electric refrigerators* that are now advertised for home use work on this same principle. Ammonia or some other volatile liquid is used in them. Electricity has nothing to do with the process except to furnish power for a motor. This motor is used to run a pump which com-

presses the gas that comes from the evaporation of the volatile liquid and turns it back again to a liquid. It is again evaporated and is used over and over (Fig. 50).

164. Cold storage. In a cold-storage plant, brine is cooled by the evaporation-of-ammonia proc-

Fig. 51. A cold-storage room. The pipes shown contain circulating cold brine. Notice the moisture condensed and frozen on the lower pipes

ess. The cold brine is run into pipes that pass through the rooms that are to be kept cold. Any desired temperature down to a little below freezing is obtained. In these cold rooms, fruit, eggs, fish, and meat are kept for months without spoiling (Fig. 51).

Why did our great-grandfathers seldom have ice cream in the summer?
Name two volatile liquids.
Why does your skin feel cold after an alcohol rub?
How is artificial ice made?
Why is ammonia usually used in ice machines?
Could any liquid other than ammonia be used in making artificial ice?
What advantage has artificial ice over natural ice?
What is the advantage of an electric refrigerator?
What part does electricity play in the process?
What is the principle of cold storage? For what is it used?

165. Preservatives. Decay germs do not grow in strong salt solutions. If fish are packed in brine, they keep, because the salt prevents the growth of bacteria. Other substances act in a similar way. Hams are cured in wood smoke, and cucumbers are placed in spice and vinegar to make pickles.

166. Some preservatives are dangerous to man. Many preservatives formerly used are now prohibited, as their action is harmful not only to decay germs, but also to people. A few are still allowed when used in small quantities. Benzoate of soda may be used to one-tenth of one per cent. Tomato catsup is sometimes preserved with benzoate. Look for the statement of the amount of preservative on the label of the bottle of catsup that you buy from the grocer. If it is pure catsup, no such statement will be found. A pure catsup, well made from fresh tomatoes, does not need a preservative. The

only possible advantage that the use of benzoate has is to preserve the catsup after the bottle has been opened. Articles containing benzoate may be, and often are, satisfactory foods, but since its addition makes possible the use of stale foods, products containing it may well be avoided.

Vinegar and spices are often used as preservatives, as in pickles. If not used to excess, they are harmless.

One has only to walk into a grocery or a delicatessen store in any town and look on the shelves to discover the great number of foods that are canned and preserved for our use.

People who live in towns and cities where large garden plots are difficult to find, spend a large part of their food money for canned goods that are prepared in huge canning factories (Fig. 47). People who live in the country where every family can have a garden, find it a source of great economy to "put up" or can their own fruits and vegetables.

If we choose fresh, clean fruits and vegetables and observe the rules of cleanliness and sterilization, we not only can enjoy the crops from our own garden in the winter but also we can save money.

Ask your butcher how corned beef is preserved.
Why does benzoate of soda preserve catsup?
Why is it well to avoid foods containing certain preservatives?
Name two ways in which you could preserve fish and explain why each would succeed.

167. Milk a perfect food. The one universal food is milk. For young children it is almost a perfect food; that is, it contains all the materials that are needed for their growth. For this reason doctors recommend that every child drink at least one pint of milk daily. Milk, because it is such a good food, is an ideal place for the growth of germs. They find in it all the things needed for their comfort, and they grow and multiply with great rapidity.

168. Why bottle milk? The farmer must use great care with milk, lest it become infected with disease germs and cause sickness among the children who drink it. If cows are allowed to drink impure water, or if the milkman has germs on his hands, or if the cow's milk bag is unclean, bacteria may fall into the milk. There they will multiply quickly, and may cause sickness. Milk sours because of the growth in it of an acid-forming germ. For all these reasons the health boards of villages and cities insist that all milk sold must be produced under the strict supervision of the law. Milk dipped from a can that is open to the air easily becomes impure, and, unless the milk is thoroughly stirred every time some is taken out of the can, it changes in composition. As cream is lighter than skim milk, it rises to the top. A dipperful taken from the top of the can will therefore have much more cream in it than a dipperful taken from the bottom. Bottled milk is much better than open-can milk, because each

bottle will contain the same amount of cream, and the milk is not exposed to germs (Fig. 52).

169. Pasteurizing milk. Heating kills bacteria. Fortunately, the dangerous disease bacteria are more easily killed by heat than are the harmless varieties.

Fig. 52. The uncovered milk can is a delight to disease-carrying flies

To make milk safe to drink, most of the milk sold in cities is *pasteurized;* that is, it is heated to 150°-155° F. for twenty to thirty minutes. This temperature is high enough to kill most of the disease bacteria without changing the flavor of the milk to any great extent. The milk is then cooled quickly and bottled. In such bottling plants, everything

used is sterilized by boiling water or steam. Such milk is safe, even for infants (Fig. 53).

170. Certified milk. Some infants do not readily digest pasteurized milk. To give such children as pure milk as possible, some dairies deliver what is called *certified milk.* This milk must come from

Courtesy Abbotts Dairies Inc.

Fig. 53. Milk-bottling machines in a modern dairy

tested cows, and these cows must be kept under the most sanitary conditions. The milk is cooled as soon as it is drawn from the cow, and bottled immediately. The *bacteria count,* that is the number of germs present, must be low. This milk costs more than pasteurized milk because of the extra

care taken to keep it clean, but it does not keep so well as pasteurized milk.

Why is milk an almost perfect food?
Why is it a good growing place for germs?
Why should every milker wash his hands before milking?
What causes milk to sour?
What are the disadvantages of milk dipped from a can?
What are the advantages of bottled milk?
What is pasteurized milk?
What is certified milk?
Why is certified milk more expensive than pasteurized milk?
Why does pasteurized milk keep better than certified milk?

EXPERIMENT 35

Question: Why is pasteurized milk safer to use than raw milk?

Materials: Desk equipment; wire; test-tube rack; raw and pasteurized milk; absorbent cotton.

Directions: Put an inch of raw (unpasteurized) milk in each of three test tubes. Label these A, B, and C. Write your name on each label, so that you will know your own test tubes. A is to be placed unsealed in a test-tube rack and kept at the room temperature for several days.

Wind a long piece of thick copper wire into a rack that will hold a number of test tubes. Biological supply houses sell these racks, but you can easily make one. Put the rack in a large pan of water and heat the water to 150° F., but not over that temperature. Plug all the B test tubes of the class with sterilized absorbent cotton and put them in the rack. The hot water will heat the milk to 150° F., but this will take some time. Heat the test tubes to 150° F. for thirty minutes, to make sure that all the milk has reached that temperature. Remove the test tubes, place them in a test-tube rack, and allow them to stand at the room temperature.

Plug test tube C with absorbent cotton and boil the milk for at least one minute. Put the test tube in a rack and let it stand at the room temperature.

At the end of two days, examine all three test tubes. 1. What has happened to the milk in test tube A? Put a piece of blue litmus paper in this test tube. Does it turn red, showing that the milk has soured? 2. Taste the milk in test tube B. Is it sweet? 3. Why do you think the milk in A soured, while that in B remained sweet? Shake the milk in C. 4. What change is made by boiling milk? (When we boil an egg, the white becomes solid. We call this change *coagulation.*) 5. Did boiling coagulate part of the milk?

Diagram: None required.

Conclusion: Answer the question.

Practical application: Pasteur, a noted French scientist, discovered that heating milk to 145° F. for a short time killed the pathogenic (disease) germs present, and therefore made the milk safe for use. This process is used almost universally today, and in his honor is called *pasteurization.*

Pasteurization does not kill all the bacteria, but it does kill the dangerous disease germs as well as many others. Pasteurized milk keeps sweet longer than raw milk. The process does not destroy its flavor or food value. Pasteurized milk, like any food, should be kept with care. It should be kept cold in the bottle in which it is bought. Always clean the mouth of the bottle before pouring out the milk.

Experiment 36

Question: Why do some manufacturers use benzoate of soda in catsup?

Materials: Desk apparatus; corrosive sublimate or mercuric chloride; formaldehyde; sodium benzoate; raw milk; a small bunch of grapes or an apple.

Directions: Pour an inch of raw milk into each of three test tubes and label them A, B, and C. To A add a few drops of mercuric chloride. (**Caution!**—this is a deadly poison!) To

B add ten drops of formaldehyde. To C add a pinch of sodium benzoate and shake until it dissolves. Let all three test tubes stand at the room temperature for three days. At the end of that time, examine them. In all three test tubes, you will find that the milk is still sweet. 1. What must all three substances have done to the bacteria present in the three test tubes?

Mercuric chloride, often called corrosive sublimate, is a very violent poison. Formaldehyde is also a poison. Sodium benzoate cannot be used by our bodies for any useful purpose. 2. What are the objections to using any of these three substances in a food product?

Suspend a small bunch of grapes or an apple from the cover of a museum jar. Fill the jar with formaldehyde. Clamp on the cover carrying the suspended grapes. Shake gently to drive out any air bubbles held by the fruit. There must be enough formaldehyde to cover the fruit completely. Label the jar "poison" and place it on a laboratory shelf. At the end of a month, examine the fruit. It will be plump and well preserved. 3. Why would it be unsafe to eat the grapes? Place the jar back on the shelf and see how long the grapes will remain fresh.

Diagram: None is required.

Conclusion: 4. Why do some food packers use sodium benzoate in tomato catsup? 5. Why is it well not to buy food containing this preservative?

NOTE: The use of $\frac{1}{10}$ of 1% of sodium benzoate in food products is permitted by the government. Its use, however, can be of no advantage to *you*, so why pay for it?

CHAPTER NINETEEN

THE HEAVENS, SKY, AND EARTH

171. We profit by experiments of early navigators. More than 400 years ago, Columbus sailed westward on his great voyage of discovery. How do you suppose he found his way over the ocean? If you should sometime be lost in the woods, how would you find your way home? In a very simple way. A compass would show you the direction in which you should travel. If you knew a little about the heavens and the location of some of the striking

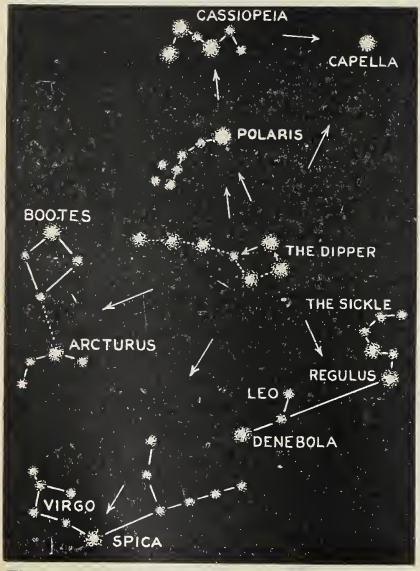


Fig. 54. Some constellations of stars around Polaris

heavenly bodies, you could use this information to guide you (Fig. 54).

172. Sun and stars are true direction guides. In very early days, men had no compasses to show them in which direction the north lay. The North Star, Polaris, which is visible at night in the Northern Hemisphere, and the sun, which shines so brightly by day, were used as guides. By studying the position of these heavenly bodies, it was possible to know in which direction they were traveling. You, too, with a little study, can learn how to find direction by watch and sun (Fig. 55).

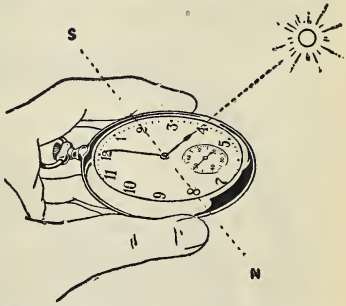


Fig. 55. How to find direction by use of a watch and the sun. See Experiment 37

How did Columbus know the direction in which he was sailing?
How do Boy Scouts find their way through the woods?
How did ancient man find his way?
How may you use your watch to determine direction?

173. Appearances are deceiving. Forget for a time what you have learned from your geography about the motions of the earth and the sun, and think only of the motions of the sun and stars *as they appear to you.* You know that the sun *seems* to rise in the east and set in the west. The stars

seem to revolve or travel around the earth in the sky, and the earth *seems* to be at the center of the universe.

174. Early beliefs. To ancient man the earth was at the center of a huge sphere. The sun and the stars were hung on the inside of this sphere, and,

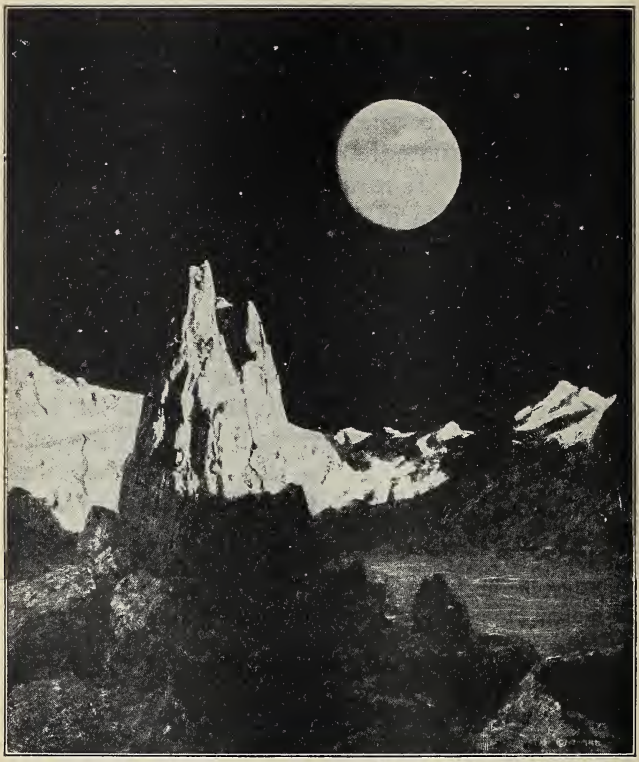
Fig. 56. The world as known to the ancients

as the sphere slowly turned, the sun and stars turned with it. To them the earth was flat and unknown, but terrible dangers threatened all who approached the edge (Fig. 56). Even at the present time some savage tribes hold these beliefs. Within the past few years there has been much said in the newspapers regarding a trip to the "edge of the earth" to be made by a man who still believes that the earth is flat.

175. Modern beliefs. All these ancient theories we now know to be false. Men have studied the stars and found other truths. By long-continued study, these *astronomers* have discovered fact after fact, until we know that the earth is a spheroid or like a sphere. It revolves continually around the sun. This motion of the earth, combined with its rotation (spinning like a top) on its axis, causes the seasons, day and night, and makes the sun and stars seem to move in the sky (Fig. 57). The next time that you take a trip on a railway or a boat, notice that, as the train or boat begins to move, it seems to you as if your train or boat were remaining stationary, and that objects outside were moving. It is this same effect that makes it difficult for us to realize that the earth is moving and not the stars.

Why did ancient man believe that the sun revolved around the earth?
Why have we come to disbelieve the theories of the ancients?
What do we now believe about the movements of the earth and sun? the shape of the earth? the causes of day and night? the causes of seasons?

176. The sun. Many early tribes were sun worshipers. This was natural, for from the sun came the light and heat that made their existence possible. We no longer worship the sun, but we are still dependent on it for light and heat.



American Museum of Natural History

Fig. 57. The earth in space as seen from the moon. From a painting by Howard Russell Butler

177. Gravity at sun's surface is great. The sun is really a hot star about 93,000,000 miles from the earth. Compared to the earth, it is huge, being

1,300,000 times as large. Because it is so large, the attraction of gravitation on the sun is very great. A man weighing 150 pounds on the earth would weigh about two tons, or over twenty times as much, on the sun.

178. It is impossible for us to appreciate the amount of the sun's heat and light. The sun sends its light and heat rays in all directions, but we receive only a small part of them. Can you imagine 6,000 candles burning only one foot from your eye? Think of the glare! This is the amount of light given by the sun. Now we know why we cannot look directly at the sun with the naked eye. The sun's heat is equal to that given out by the burning of about 8,000,000,000,000 tons of coal a second.

If it takes an air-mail plane 30 hours to fly from New York to Los Angeles (3000 miles), how long would it take the same plane, flying at the same rate, to cover the distance between the earth and the sun?
The diameter of the sun is about 864,000 miles, of the earth 8,000 miles. If we represent the diameter of the earth by a line one inch long, what would be the length of the line representing the diameter of the sun?
Why does the earth receive so few of the sun's rays?

Experiment 37 (Home)

Question: How can I find north in the daytime without a compass?

Materials: A watch and the sun.

Directions: It is sometimes a convenience to be able to find north in the daytime without the use of a compass. Its position may be roughly determined by the use of a watch.

Hold the watch in your hand, with its face parallel to the ground. Point the hour hand toward the sun. An imaginary line drawn through the center of the dial and a point halfway between the hour hand and the figure marking 12 o'clock will point roughly north and south. This is true between the hours of 6 A.M. and 6 P.M.

Study the diagram (Fig. 55) so that you are sure just what is meant, then try it. Confirm your result by consulting a compass.

Diagram: Show a north and south line determined by this method when the time is 4 P.M. (Fig. 55).

Conclusion: Answer the question.

Practical application: This method is sometimes of use when you are in the woods and have no compass.

Experiment 38

Question: How may one locate the position of the North Star (Polaris)?

Materials: A compass and the sky at night.

Directions: (*a*) On a clear night locate the Great Dipper in the sky. (See Figs. 54 and 61.) You can easily recognize this. The stars composing it are bright, and their arrangement makes them easily found.

(*b*) When you have found the Great Dipper, in imagination draw a line through the two stars that form the outside of the bowl. These two stars are called the *Pointers*. This name is given to them because they point almost directly toward Polaris. Your imaginary line if continued will almost pass through Polaris, which will be found at a distance from the Pointers about five times as great as the distance between them.

(*c*) Polaris is part of the constellation named the Little Bear (*Ursa Minor*). It is at the end of the handle of the Little Dipper. The position of all these stars is shown in Figure 54.

Diagram: Show the Great and Little Dippers, the Pointers, and Polaris (Fig. 61).

Conclusion: Answer the question.

CHAPTER TWENTY

EARTH AND HER NEIGHBORS

179. Solar system: planets and planetoids. Revolving around the sun are nine smaller bodies that we call *planets*. The word "planet" means wanderer, and was given to these bodies because they seem to wander about the sky. Starting from the sun we name them: Mercury, Venus, Earth (our planet), Mars, Jupiter, Saturn, Uranus, Neptune, Pluto. Between the *orbits*, or the paths, of Mars and Jupiter a swarm of minor planets, called *planetoids*, have their orbits. They are small, the largest known being only 400 miles in diameter.

180. Paths of planets are elliptical. If you will take a hoop and press the opposite sides together slightly, you will change the circular hoop into an ellipse. Such a shaped figure is said to be *elliptical*. All these planets revolve around the sun in elliptical paths or *orbits*.

Courtesy Yerkes Observatory

Fig. 58. Jupiter and its four large moons as seen through a telescope

181. Moons are satellites. The earth is a planet, and, as you

know, has a moon that revolves around it. Other planets have moons also, or, as they are often called, *satellites*. Jupiter is especially well provided with satellites, as it has eight (Fig. 58). All

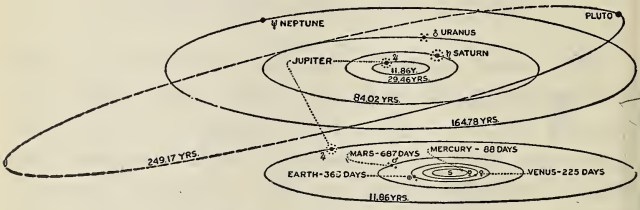


Fig. 59. The solar system

these bodies, sun, planets, planetoids, and satellites, we call the *solar system* (Fig. 59).

Why was the name "planet" given to the nine bodies that revolve around the sun?
What is a planetoid?
What is meant by the orbit of a planet?
What is its shape?
What is a satellite?
What constitutes the solar system?

182. Our planet, earth, seems best fitted to man. It is interesting, but hopeless, to wonder whether life exists on other planets. Certainly, man would find it difficult, if not impossible, to live on any of the other planets, yet some form of life may exist there. Mercury and Venus always turn the same side to the sun. This side must be very hot, while the other side must be very cold. Mars has an

exceedingly thin atmosphere, which will hold but little heat, and, since it is farther from the sun than is the earth, it must be colder. It is possible, though, that life of some kind does exist on Mars. The five outer planets are so placed that it is almost certain that life cannot exist on them.

183. We do not know that there is life on Mars. We often read in the papers about the canals of Mars, and statements to the effect that they prove that Mars is inhabited. Remember that Mars, as seen in the telescope, is a circle about the size of a twenty-five-cent piece (Fig. 60). Imagine the earth reduced to this size, and then imagine the difficulty of trying to decide much about its condition. There may be canals on Mars, and this may prove that it is inhabited, but we do not know. All such speculations are interesting, but as yet are speculations only.

Courtesy Yerkes Observatory

Fig. 60. Mars as seen through a telescope

Why is it difficult to believe that life can exist on Mercury and Venus?
Why do some astronomers believe that Mars may be inhabited?

CHAPTER TWENTY-ONE

SOMETHING ABOUT OUR PLANET

184. Man's planet, the earth. Naturally, the planet in which we have the most interest is the one on which we live, *the earth.* The earth is one of the smaller planets, being about 8,000 miles in diameter and about 93,000,000 miles distant from the sun, around which it revolves once a year. It rotates on its axis once every twenty-four hours. Its equatorial diameter is twenty-six miles longer than its polar diameter; that is, it is not a perfect sphere; it is slightly flattened at the poles.

185. The earth is an oblate spheroid. Take a tennis ball and squeeze it between your hands so as to flatten it slightly. You will have an exaggerated model of the earth. The cloth, the outside covering, will represent the uneven surface of the earth, with which we are familiar. The rubber inside represents the core of the earth. A sphere flattened as you flattened the tennis ball is called an *oblate spheroid.* This is the name we give to the shape of the earth.

What is the diameter of the earth?
How far is the earth from the sun?
Explain the difference between revolution and rotation.
How long does it take the earth to make one rotation? one revolution?

What is the difference between the shape of a billiard ball, which is a perfect sphere, and that of the earth? What name do we give to the shape of the earth?

186. The earth's axis is tilted. The *axis of the earth* is an imaginary line that passes through it. The ends of the axis are the two poles. If you will imagine the axis continued out into space, you will find that one end of it almost strikes the North Star (Fig. 61). This end of the axis is the North Pole; the opposite end is the South Pole. This axis is tilted out of a vertical position at an angle of $23\frac{1}{2}°$. As we shall see later, it is this tilting or slanting of the earth's axis that causes the unequal length of days and nights.

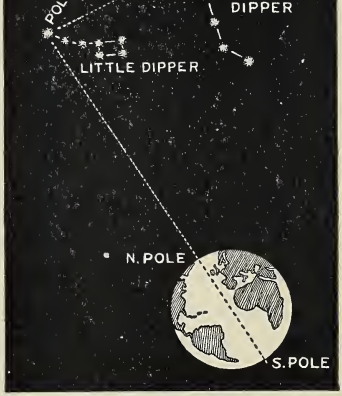


Fig. 61. Finding the north by the use of Polaris

187. The universe so large; we so small. No matter how hard one may study the printed page, it is difficult to understand the motions of the earth and the seeming effects that these motions produce on other heavenly bodies. We are so small, and the universe so huge, that to help us realize the

effects of these motions of the earth, we must use a model. In Experiment 39 this is done, but it will help you to understand this experiment if you will try an experiment in the form of a game in the school yard. (Sec. **188.**) You doubtless know that *light rays travel in straight lines.* Possibly you never thought of it in just this way before, but on thinking about it, you know that it must be true. One cannot see around a corner, as he could if light rays curved. Man depends on this fact when he throws a ball or sights a gun.

What is the axis of the earth?
What are its ends called?
What determined the name of the star which we call Polaris or the North Star?
How much is the earth's axis tipped away from the vertical?
Give three facts that prove that light travels in straight lines.

A study of the variations between the calculated and the observed orbits of the planets led Percival Lowell, an American astronomer, to believe that there was another undiscovered planet beyond the others. He made his calculations, and in 1930 the observatory at Flagstaff, Arizona, when studying some photographs of the heavens, found a small object that they believed to be this new planet. It has been named Pluto. Whether it is really a new planet or not is as yet in doubt, for astronomers have not yet enough data (facts) about it to determine its orbit accurately.

CHAPTER TWENTY-TWO

DAY AND NIGHT, WINTER AND SUMMER

188. Day follows night; night follows day: June 21. Chalk as large a circle as you can on the school-yard pavement, or, if the yard is grassed, lay the circle out with tape or string. A circle about forty feet in diameter will do. On opposite sides, narrow the circle a little so as to change it into an ellipse. Select a boy or a girl from the class to stand one foot from the center, to represent the sun. The ellipse represents the path of the earth around the sun, or its *orbit*. (See Fig. 62.) Borrow a croquet ball and chalk on it a north and a south pole. Drive wire nails in at these two points to represent the ends of the axis of the earth. Mark a spot to represent the place where you live. Hold the ball at one end of the ellipse (A in Fig. 62) so that your home spot faces the sun.

Tip the north pole of the ball so that it points toward the North Star. Imagine the North Star to be visible in the sky. Probably you will find a tree or a chimney top that can represent it. An imaginary line passing through the north and the south poles and the North Star will represent the axis of the earth. The ball will represent the earth; your

mark, the place where you live; and your position on the ellipse, the position of the earth on June 21 of any year.

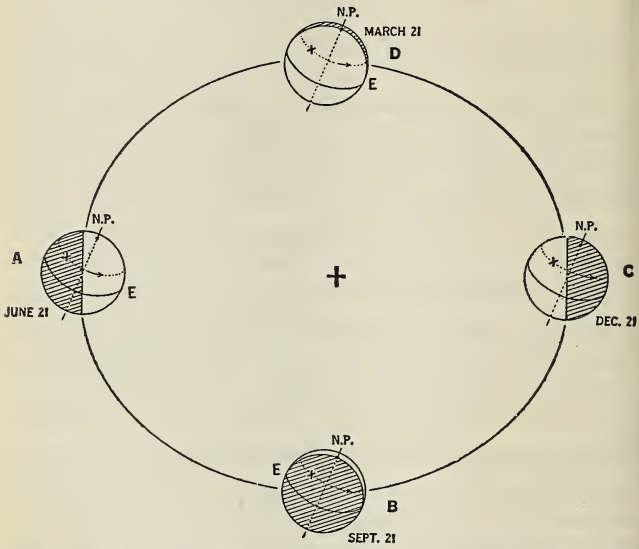


Fig. 62. The cause of day and night. N.P., north pole; E, equator; X, your home town; +, where boy stands representing sun

Turn the spot where you live toward the sun. It is now *daytime*. Rotate the ball slowly, keeping the north pole always pointing in the same direction; that is, toward the North Star. You will find that your home spot will gradually get into such a position that the straight rays of light from the sun cannot

reach it. It is now *night,* because the rays of light can no longer reach you. Make one complete rotation of the ball and notice that during *more than half the turn,* the sun shines on your home. That is, daylight lasts more than twelve hours.

The boy or the girl who represents the sun will tell you that at no time was the north pole of the ball (the earth) out of sight. At the North Pole of the earth then, daylight must last twenty-four hours. As the North Pole is pointed toward the sun, the South Pole must be pointed away from it, and will receive no light at all. That is, on this date at the South Pole, night lasts twenty-four hours. This simple experiment will show more about day and night than pages of description.

What accounts for the fact that on June 21 the North Pole has twenty-four hours of continuous daylight, and the South Pole twenty-four hours of continuous darkness?
When will the North Pole have twenty-four hours of continuous darkness.

189. Revolution: September 21, December 21, March 21. Walk counterclockwise (opposite to the direction which the hands of a clock follow) one-quarter way around the ellipse, keeping the north pole always pointing toward the North Star. The earth is now at September 21 of any year (Fig. 62). Repeat the rotation of the ball. As it turns, you

will find that a half turn hides the sun; that is, daylight lasts twelve hours for your location.

190. Periods of daylight and darkness. Walk another quarter of the way around. This will put you at the opposite end of the ellipse from your first position (Fig. 62). The north pole of the ball must still point toward the North Star; that is, it must point away from the sun. The date is December 21. Once more rotate the ball. You will find that now a person at the North Pole cannot see the sun. That is, it is always night there, while the South Pole has twenty-four hours of daylight. A person at your home will be able to see the sun during less than half a turn. That is, your home town has now less than twelve hours of daylight.

Walk another quarter turn to a point opposite September 21. It is now March 21. Here you will find the same things to be true that were true on September 21. Exactly a half turn will hide the sun. Days and nights are everywhere each twelve hours long.

Go back to the first position and hold the ball so that the north pole is vertical. Rotate the ball. You will see now that the days and nights are everywhere twelve hours long. This shows that it is the inclination (tipping) of the earth's axis that causes the unequal length of days and nights where you live. The earth's axis is really tipped $23\frac{1}{2}$ degrees; for this reason, on this day, June 21, all the

earth from the North Pole to the Arctic Circle has a day of twenty-four hours, while from the South Pole to the Antarctic Circle there is a night of twenty-four hours.

Illustrate and explain what is meant by counterclockwise.
Why does St. Louis have long summer days and short winter days?
On what two dates does the entire earth have twelve hours of daylight and twelve hours of darkness?
What would be true about the length of day and of night at any time of the year if the earth's axis were not tipped? Why?

EXPERIMENT 39

Question: What causes day and night? What causes the seasons?

Materials: School yard; chalk and string or tape with hairpins; small globe representing the earth, mounted on an inclined ($23\frac{1}{2}°$ to vertical) axis.

Directions: (*a*) Draw, using chalk and string, as large a circle as you can on your paved school yard. If possible, the circle should be at least 40 feet in diameter. Mark the center of the circle. If your yard is grassed, use a piece of white tape or string to mark the circle. Hold the tape in place by passing hairpins over it and then into the ground. Narrow the circle slightly at opposite sides so as to change the circle into an ellipse. This ellipse represents the earth's orbit. (See Fig. 62.)

(*b*) Place a boy one foot from the center, on the long axis of the ellipse. He represents the *sun*. 1. Why was the boy not placed at the center of the ellipse? 2. Why was the circle you drew changed into an ellipse?

(*c*) Place a boy holding the small earth globe at **A**. Mark your home town on the globe with a chalk mark. Holding the earth so that the North Pole points toward the sun, and is inclined at an angle of $23\frac{1}{2}$ degrees to the vertical, turn the globe

so that the chalk mark on your home is toward the sun. This represents the earth's position at noon on June 21. The advantage of the small mounted globe is that if you hold it by the wire base you can easily turn the earth and at the same time keep the axis pointed in the right direction. Stand just in front of the sun, between the sun and earth, and facing the earth. You will see that the sun's rays are falling almost vertically on your home. It is day there. Stand just as you are and have the boy holding the earth rotate it. At one position you can just see your home. It is twilight there now. As the rotation continues, your home disappears on the other side of the earth. It is night there now. Remember that light rays travel in straight lines. If you cannot see your home, a person living there cannot see you. As the sun's rays do not strike your home, it must be night there. 1. What causes day and night? 2. At this time of the year will day or night be the longer at your home? Why? For the exact length of the day, consult an almanac.

(*d*) Still keeping your place, watch the north pole of the earth while the earth is being rotated. 1. Is the north pole invisible at any time during the rotation? How many hours of sunlight will the north pole have during a day of twenty-four hours? Repeat the rotation of the globe. Try to see the south pole. 2. Is the south pole visible at any time? How many hours of darkness will the south pole have during a day of twenty-four hours? 3. Fill in the table, using the facts you have found out.

(*e*) Move the earth to B and repeat your observations. B represents the position of the earth on September 21. Fill in the table.

(*f*) Move the earth to C, which represents its position on December 21. Repeat your observations and fill in the table. Notice that now the north pole is pointing away from the sun and that it is the south pole that has no night.

(*g*) Move the earth to D. This represents its position on March 21. Repeat your observations and you will see that once more days and nights are of equal length over all the world.

TABLE

On June 21 the North Pole has ..... hours of sunlight and ..... hours of night. My home town, ..., is in latitude ..... and longitude ..... It has ..... hours of sunlight and ..... hours of night. It is summer in the ..... hemisphere and winter in the ..... hemisphere.

Repeat for each date. September 21
December 21
March 21

Diagram: Make a sketch showing the position of the earth at each of the four seasons (Fig. 62).

Conclusion: Explain the cause of day and night.

Practical application: At the North Pole one sometimes finds days of twenty-four hours of sunlight, and at other times days of twenty-four hours of darkness. This is due to the tipping of the axis of the earth. If the axis pointed straight up, all days, everywhere on the earth, would be equally divided between sunlight and darkness. See if you can imagine what would be true if the axis of the earth pointed directly toward the sun. You can find the exact number of hours of sunlight that your home town has on any date by referring to an almanac.

Note: The earth rotates on its axis, and revolves around the sun.

In our country, the warmest days come when the earth is farthest from the sun. This is of course just the opposite of what one would expect. The explanation is that in summer the days are long, and the sun's rays strike the earth more directly and for a longer time than they do in winter. In spite of the fact that the sun is slightly farther from the earth at this time, the earth really receives much more heat from the sun than it does in winter. Do you think that these facts would be true if the axis of the earth were not tipped toward the sun?

CHAPTER TWENTY-THREE

SATELLITES, PHASES, AND ECLIPSES

191. Phases of the moon. Around the spot that represents June 21 (Fig. 62), draw a ten-foot circle to represent the orbit of the moon. Hold the earth ball at the center of this small circle and let a friend hold a baseball at the spot marked "M" on Fig. 63. This baseball will represent the moon. As you doubtless know, the moon does not shine with its own light, but we see it by sunlight that is reflected from its surface. With the moon at "M," opposite to you and the sun, the moon will be fully lighted. The moon is *full.* A *phase* of the moon is the appearance of the moon to us on account of its position. The outer circle of moons in Fig. 63 represents the appearance of the moon to us at different times in the month.

192. The moon wanes and waxes. Slowly revolve the moon in its orbit around the earth. The part of the moon that can reflect light to your eyes will slowly decrease. The moon is on the *wane,* or decreasing. When it has been moved one-quarter of the way around, the moon will be half full (Fig. 63). Continue the motion in the same direction. Another quarter will bring the moon

between you and the sun. It will be almost invisible, and the moon will be *new* (Fig. 63). Move it another quarter of the way along its orbit. The moon is now *waxing*, or increasing. Finally, when it comes back to its first position, the cycle is complete and the moon once more is said to be full (Fig. 63). It takes the moon about twenty-eight days to make this circuit of the earth. This is the length of a lunar month.

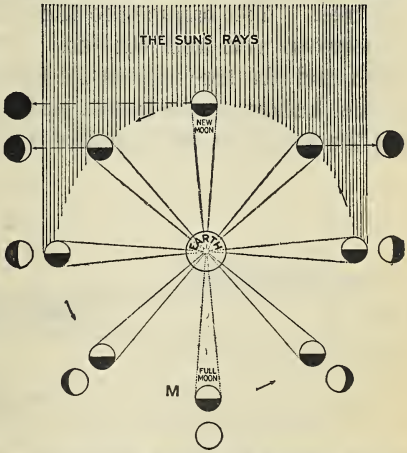


Fig. 63. The phases of the moon

As the moon in its revolution about the earth every 28 days moves through the first, second, third, and fourth "quarters" of its orbit, its form, or "phase," seems to change. The portion of the moon between the lines indicates the part opposite the eye of the observer on earth, the white, or illuminated, portion only of this part being visible. The white area of the outer circle of phases shows the moon as it appears to the observer at these phases and as it is usually represented

What is meant by a phase of the moon? Explain waxing and waning of the moon.

Draw a diagram showing the relative positions of the earth, sun, and moon when the moon is (*a*) full, (*b*) new, or (*c*) half full. What is meant by the term "lunar month"? What is its length in days?

193. Shadows. A tree in sunlight casts a shadow. That is, the trunk of the tree stops the sunlight that falls upon it, and this absence of light on the ground causes a shadow. Step into the shadow of the tree. You cannot see the sun because the tree is between you and the sun. If you represent the earth and the tree represents the moon, you will be in the shadow of the moon, and because you cannot see the sun, you will say that the *sun is eclipsed.*

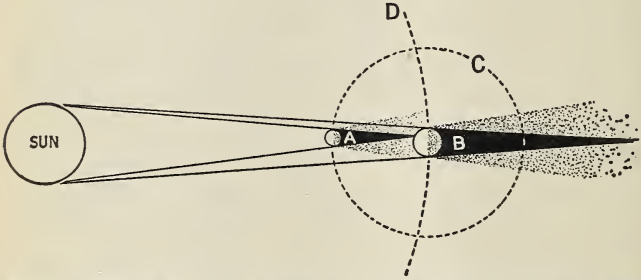


Fig. 64. Where the moon's shadow touches the earth, the sun will be invisible, or eclipsed. A, moon's shadow; B, earth's shadow; C, moon's orbit; D, orbit of earth

194. Eclipse of the sun. Stand on the spot that represents June 21 (Fig. 62) and face the sun. Have a friend hold the ball that represents the moon between you and the sun. You will find that when the moon is in one particular position, you cannot see the sun. When this occurs, the sun is eclipsed. The earth is in the moon's shadow. Since the moon is very small compared with the sun or the earth, this

shadow of the moon will cover only a small portion of the earth's surface. Eclipses of the sun are rare, and are visible only over a small portion of the earth's surface (Fig. 64).

195. Eclipse of the moon. Sometimes the sun, the earth, and the moon are all in the same straight line, with the moon on the side of the earth opposite to the sun. The moon is then in the earth's shadow. This causes an eclipse of the moon (Fig. 65). These

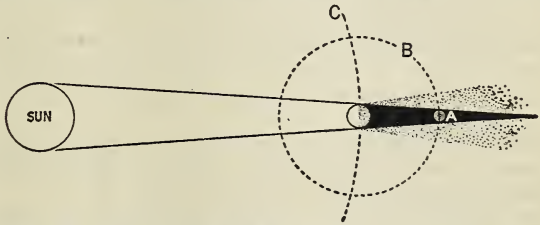


Fig. 65. A total eclipse of the moon. A, moon covered by earth's shadow; B, orbit of moon; C, orbit of earth

eclipses are much more common than eclipses of the sun, because the earth's shadow is much larger than that of the moon. They may be seen from a large portion of the earth's surface. An almanac gives the dates of these eclipses. Perhaps your father will let you stay out to see one.

What is the cause of a shadow?
Draw a diagram showing an eclipse of the sun.
Draw a diagram showing an eclipse of the moon.
Why are eclipses of the moon commoner than eclipses of the sun?

Experiment 40

Question: What makes the moon wax and wane?

Materials: The same arrangement as in the day and night experiment, with the addition of a small rubber ball to represent the moon.

Directions: Draw around A (Fig. 62) a circle ten feet in diameter. Stand at A and face the sun. Have a boy hold the rubber ball, that represents the moon, between the earth and the sun. Look at the moon (the rubber ball) and you will see that the sun's rays are striking on the side of the moon that is turned away from you. The moon will be new. Carry the moon counterclockwise around its orbit. Notice that you can see more and more of the surface of the moon that is lighted by the sun. The moon is waxing. When the moon has been carried one-quarter of the way around its orbit it will be half full. (Fig. 63.)

Continue the revolution of the moon. You will see more and more of the lighted surface. When the moon has been carried halfway around its orbit it will be full.

Continue the revolution. During this time the moon is waning. When it is three-quarters of the way around its orbit, it will once more be half full.

Continue the revolution of the moon to its original position. The cycle is now complete and the moon is ready to start on a new journey around the earth. As it takes roughly twenty-eight days for the moon to complete its course around the earth, the lunar month is twenty-eight days long.

Diagram: Show the position of the moon at four points during its course around the earth (Fig. 63).

Conclusion: What causes the phases of the moon?

Experiment 41 (Home)

Question: What is the cause of shadows and of eclipses?

Material: A large tree on a clear day.

Directions: On a day when the sun is shining brightly, look at the shadow that is cast by a large tree. The rays of sunlight are coming from the sun in straight lines. The trunk of the tree is opaque (light cannot pass through it). 1. Why do you see a shadow of the tree on the ground?

Stand close to the tree in its shadow. Imagine that you are the earth and that the tree is the moon. Look toward the sun. 2. Why can you not see the sun? When this happens in nature, we call this inability to see the sun an *eclipse.* 3. In your position, is the eclipse total or partial?

Move until you can see part of the sun. You will find that you are now only partially in the tree's shadow. The moon (the tree) is now causing a partial eclipse of the sun. If you will examine Figures 64 and 65, you will understand eclipses better.

Conclusion: Answer the question.

NOTE: You have noticed how the length of your own shadow varies at different times of the day. The cause of these differences is the varying height of the sun above the horizon during the day. To get a more accurate knowledge of this fact, set a stick vertically in the ground in an open space. Start the experiment in the morning. Mark the position of the end of the shadow of the stick at nine o'clock, by putting a small stick in the ground at the end of the shadow. Repeat this each hour during the day. This will demonstrate two things: first that the shadow varies in length and, second, that the shadow falls in different directions at different times of the day.

After you have made this study, you will be able to read with more understanding and more pleasure Robert Louis Stevenson's poem "My Shadow."

CHAPTER TWENTY-FOUR

STARS, SUNS, AND UNIVERSES

196. Stars are suns. The sun is a star, similar to the stars that are seen on a clear night. Many stars are much larger than the sun, and are, of course, much farther away. This is the reason why they look so small. They are so far away that their distance is beyond comprehension. The best way to realize their immense distance is to say that light travels so fast (186,000 miles a second) that it can go around the earth more than seven times in one second. Many stars are so far away that if they had been destroyed when the Pyramids were built, they would still appear to us to be shining in the sky.

197. Colors of stars change with age. The color of stars is due to their temperature. The younger the star, the hotter it is and the whiter it appears. As it cools, the color changes, just as the color of a white-hot piece of iron changes to yellow and then to red as it cools. Stars are made of the same elements that compose the earth, and there is no reason why many of them should not have planets revolving around them, just as the sun has. Possibly life may exist on these planets, but no one knows, and we can spend our time in better ways than in wondering if

this be true. You may think it very hard to believe that man can know so much about stars that are so distant, but, when you study astronomy, you will be given the proofs. We cannot give them here.

What difference is there between our sun and the stars?
Why do other stars appear to be smaller than our sun?
How fast does light travel?
Why are we not sure that all the stars we seem to see in the heavens really exist?
Why are some stars white, while others are red or yellow?
Might it be possible that other solar systems than ours exist? Explain.

198. Comets are visitors. Every now and then a large, luminous, hazy object appears in the heavens, swings around the sun, and then disappears. This is a *comet* (Fig. 66). Comets are masses of thin gas. They have a bright head and a luminous tail streaming from it. The head is the brightest part of the comet, showing that it is somewhat denser than the tail. The tail always points away from the sun, so that, to our view, it is behind the comet as it approaches the sun and in front of it as it leaves. Even the head must be very thin, for it is possible to see stars through it. Sometimes comets are bright enough to be seen without the aid of a telescope, but usually they are so faint that only astronomers notice them.

199. Comets have large orbits. Men formerly thought that comets were dangerous, but now we

know that they are harmless. Even though the earth should pass through the tail of a comet, one would never know it. Often these comets never return, but some of them, as Halley's comet, do.

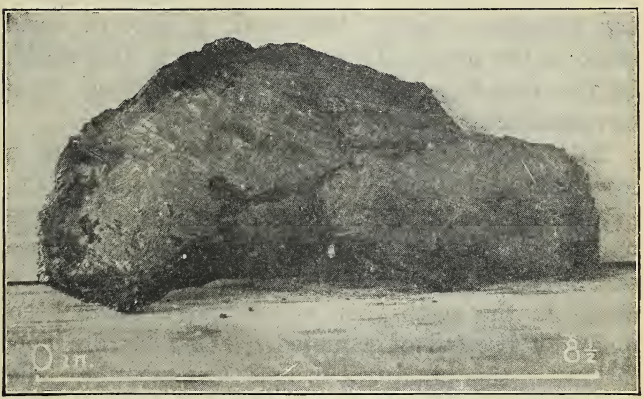
Courtesy Yerkes Observatory

Fig. 66. Halley's comet as seen in 1910

This was last seen in 1910 and, as it takes seventy-five years to swing around its orbit, it will not be seen again until 1985.

Of what is a comet composed?
Under what conditions does a comet move (*a*) headforemost? (*b*) tailforemost?

200. Meteors, friction, heat. Have you ever made a wish on a "shooting star"? These *shooting stars*, or *meteors*, are small masses wandering in space. If they chance to come near to the earth, the force of gravitation draws them to it. They are traveling with a high velocity, or rate of speed, and,



Courtesy Yerkes Observatory

Fig. 67. A meteorite composed of iron and nickel

when they rush through the air, friction heats them so hot that they throw off a shower of sparks. *Meteorites*, which are fallen meteors, are often composed of iron, and, as you know, iron burns if it is heated sufficiently (Fig. 67).

That friction may cause heat is a common experience. Place a piece of paper over the end of your finger and then rub it briskly on the desk. You

will soon have proof that friction develops heat. It is to diminish friction that oil is used in automobiles and sewing machines. You might gather from this that friction was always to be avoided, but think what would happen to you if there were no friction between your feet and the ground. How would you walk? Without friction how could a trolley car move or stop, or how could a piece of steak stick to the fork? Like most things in this world, friction is a help or a hindrance, depending upon circumstances.

201. Meteorites come to earth. Sometimes a meteor is so large that not all of it is burned up, and the remainder strikes the earth. Many of these meteorites have been picked up, and you may see one in almost any museum. In Arizona there is a crater in the earth that is believed to have been made by the fall of a meteor. Scientists are now digging in this pit to try to find the meteorite. The metal in it may be very valuable.

What is a shooting star or meteor?
What is a meteorite?
What causes the stream of light behind a meteor?
Why do meteors seldom reach the earth?
Name two instances in which friction is an advantage and two in which it is a disadvantage.
Why do we put ashes on icy sidewalks?

CHAPTER TWENTY-FIVE

MYTHS AND NOTIONS

202. More superstitions. Ancient man had many gods and many myths. Rocks, trees, and fabulous animals—all were inhabited by spirits. Man feared many things which we now know to be harmless. Thunder was the voice of a god speaking in anger.

203. Constellations. The stars were even more wonderful to them than they are to us. They used them in finding direction, but knew little of their real nature. Their imagination was vivid, and they peopled the sky with many imaginary giants. They saw marked out in star groups, called *constellations*, a great bear, a giant, Orion, with a huge club, threatening a bull, and many other strange images. A star atlas will give you these constellations and their names.

204. A bear story. Two of these constellations, Ursa Major and Ursa Minor, or the Great Bear and the Little Bear, have this story. Callisto, a young maiden, had a small son named Arcas. Juno, jealous of Callisto because of her beauty, changed her into a bear, and her son Arcas, who had grown up and become a mighty hunter, was about to kill the bear

who was really his mother. Jupiter, to prevent this, put them both into the sky, and there they may be seen shining every night. We are interested in these two constellations because of the *North Star*, or *Polaris*, the most important star in the Little Bear. Both of these constellations are so near the North Pole of the heavens that they may be seen all the year.

205. Polaris, the North Star; the pointers. If you know only one star, the North Star is the one whose location you should learn. Find the Great Dipper in the sky. The *pointers* are the two stars that form the side of the dipper farthest from the handle (Fig. 61). This name is given to these two stars because they point toward the North Star. It is about five times as far from the North Star to the nearer pointer as the distance between the pointers.

Polaris may also be found by locating the Little Dipper. It is the end star in the handle. Polaris is the best known star in the Little Bear. It is so far away that its light takes about two hundred seventy-five light years to reach the earth.

206. Apparent movements of stars due to movements of the earth. Look at the Little Dipper in the autumn and you will see that it is upside down. Water would spill from it. On the other hand, the Great Dipper is right side up. Observe it in the spring, and you will see that their positions are reversed. The Great Dipper is now upside down,

while the Little Dipper is right side up. This change is caused not by the motion of the stars, but by the motion of the earth in its revolution about the sun.

You will doubtless find a star atlas in your school library. Possibly your science teacher will let you have a small copy of this map. Study this map, until you know the position of some of the main stars in the constellations around the pole. Then at night go out, and, with the help of your map, see if you can find these stars in the sky. This is one science subject for which you need no laboratory built by man. The vault of heaven is laboratory, diagram, and materials all in one.

Name three constellations and tell how the names originated.

Draw a diagram showing how to locate the North Star in two different ways.

Why do constellations appear to change their positions in the heavens?

CHAPTER TWENTY-SIX

CLIMATE AND WEATHER

207. Distinction between climate and weather. City people need not pay much attention to a rainy day. Business and school go on just the same. In fact, about the only thing connected with city life that is seriously affected by rain is recreation. With country people, though, life is different. The farmer cannot plow nor plant his crops when the ground is too wet. At harvest time, the rain must be reckoned with from day to day. Such *daily* changes as rain or sunshine, heat or cold, calm or wind, we call *weather*. These daily changes are recorded by the U. S. Weather Bureau.

208. Climate. In southern California, during the summer, there is no rain. The days are fair and the nights are cool. In Seattle, during the spring, a fine soft rain falls nearly every day. Such seasonal facts as these we call *climate*. In October the climate of New York is usually pleasant. The days are fair and cool and the air is brisk and invigorating. On some particular day, however, the weather may be hot and rainy. Climate is the usual condition; weather is what the conditions may happen to be at one particular time in any climate.

What is the distinction between climate and weather?
What is the summer climate of the place in which you live?
What is the weather today?

209. What will the weather be? The city boy may read the weather report in the newspaper, but generally he does not realize its importance so much

Courtesy W. R. Ames Co., San Francisco

Fig. 68. Smudge pots form a blanket of smoke and prevent the fruit from freezing

as does the country boy. Most of the work on a farm is dependent on the weather. Rain delays the haymaking; a frost may kill early fruit buds; a drought may kill the corn. A foreknowledge of some of these things does not always help the farmer, but often it may save his crop. In California, advance notice that a heavy frost is coming is a warning to the

orange growers to light their smudge pots and heat the air in their orchards. This often enables them to save their orange crops (Fig. 68).

210. Weather forecasts are useful. In the city weather reports are very useful. Department stores will not spend extra money on advertising bargains when the weather man says "rainy." Restaurants lay in supplies according to the weather and the shoe stores get out their stocks of rubbers when rain is predicted.

It needs no argument to show the advantages to the sailor of knowing in advance the probable weather. When storm signals are flying, wise captains make their ships snug and tight.

211. The weather man rarely fails. The Weather Bureau of the United States collects records of the weather conditions daily from hundreds of observers in all parts of the country. These reports are telegraphed to Washington. The weather men study the probabilities for the next day. It is true that they are not always correct, but generally they are. Fortunately the reports that are the most valuable to the country are the ones that are most often correct.

Sometimes you may hear grumblings about the cost of the Weather Bureau. During the great Mississippi flood in 1927, the bureau's accurate predictions of the height of the flood and the date when it would reach its highest point saved many times

the cost of the bureau for several years. When the predictions of weather come true, as they usually do, we forget to give credit to the men who give us the advance information. When, on a picnic day, the prediction fails, it makes a great impression on us and we speak about it.

Thanks to the radio, the farmer can now make full use of weather reports. In California, for example, as has been mentioned in Section 209, it is very important that the fruit growers receive advance warning of a probable frost. When the weather man in Los Angeles thinks that a frost is coming, a notice is sent out over the radio, warning of the danger, and the farmers than take the necessary precaution and light their smudge pots. You might think it impossible to warm all outdoors, and of course it is. These smudge pots, however, give off a heavy blanket of smoke and warm air over the orange trees. By preventing the heat of the earth from escaping, as well as by giving off heat, they do prevent in many cases the freezing of the crop.

Name two ways in which the weather report is valuable to the farmer.
How do merchants profit by weather reports?
Why is it unreasonable to complain about the cost of the Weather Bureau?
What use have you ever made of the weather reports?

CHAPTER TWENTY-SEVEN

CLIMATE AND THE THERMOMETER

212. What heat does to things. Everyone knows that when a piece of iron is put over a fire, it gets hot. But something else also happens. The iron *expands;* that is, it grows larger. This same thing happens with many other substances. If we heat air, water, alcohol, or mercury, each will expand.

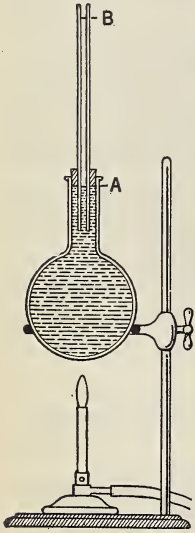


Fig. 69. A, water level before heating; B, after heating

213. Expansion and contraction. We can prove this very easily. Fill a flask with colored water and cork it with a rubber stopper through which a glass tube passes (Fig. 69). If the flask is full of water when you put in the stopper, the water will be forced up the tube until it stands several inches above the top of the flask. When you put in the stopper, be careful to see that there are no air bubbles in the neck of the flask.

Warm the flask. The water inside will expand, and this will

force the water farther up the tube. The hotter you heat the flask, the more the water will expand and the higher it will rise in the tube.

Place the flask in a jar of ice water. The water inside the flask will cool. It will *contract*, or grow smaller, and the level of the water in the tube will fall.

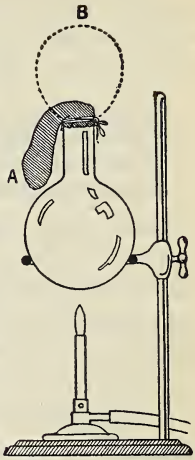


Fig. 70. Balloon showing expansion of gases. A, before heating; B, after heating

214. Gases. We can show that air expands by a similar experiment. Stretch the neck of a toy rubber balloon over the mouth of a flask, and then heat the flask. The air will expand and stretch the balloon (Fig. 70.)

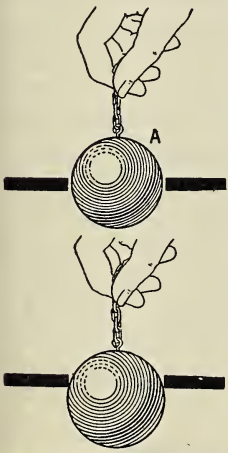


Fig. 71. Before heating, the iron ball A passes easily through the hole B. After heating, A has expanded and will no longer pass through B

215. Solids. A simple way to show that heat expands solids is to use an iron ball that will just pass through the hole in an iron plate (Fig. 71). When the ball is cool, it will easily go through the hole, but if we heat the ball, it will

expand and cannot be passed through the hole. Other metals expand in the same way, but the exact amount of expansion varies.

What is meant by expansion? by contraction?
Prove that water expands when heated.
Prove that air expands when heated.
Prove that iron expands when heated.

216. Some applications of expansion. Every country boy has seen another proof that iron expands when heated. When the blacksmith makes an iron tire for a wagon wheel, he makes it a little too small to fit the wheel. Then it is expanded by heat so that it can be slipped on the wheel. As it cools, it contracts and holds the rim and spokes firmly. This expansion of iron is so great that the cables that support the Brooklyn Bridge, which are 6,016 feet long, are about three feet longer in summer than in winter.

Heavy glassware is often broken by being put into very hot water. This is due to the outer surface expanding before the inner part. The remedy is simple. Put the dish into lukewarm water and raise the temperature gradually so that all parts of the glass will become heated and will expand at the same rate.

What holds the tire tightly on the wagon wheel?
Why are the cables of the Brooklyn Bridge longer in July than in December?
Why does your mother wash the thin drinking glasses in hot water, but washes the pieces of cut glass in lukewarm water?

How would you use your knowledge of heat and expansion to loosen a tight glass stopper from a bottle?
Why is there a larger space between the ends of the rails of a railroad in January than in July?
Why does a hot-air balloon rise?

217. A simple thermometer. Before one can understand climate, he must know something about the use and construction of a *thermometer* and a *barometer*. We shall have occasion to speak of some other weather instruments, but these two are the main dependents of the weather man. We have seen that heat expands solids and liquids. The working of the ordinary thermometers depends on the expansion and contraction of liquids. This expansion and contraction may be used to measure temperature.

218. Making a thermometer. A simple thermometer may be made by setting up a flask filled with colored water and closed by a stopper having a narrow glass tube running through it. Put a paper band around the tube at the water level (Fig. 72). Mark this level with the temperature of the water, which will be the same as the temperature of the room. Then put the flask in hot water at 100° F., and put a second paper band at the new level of the water. Mark this 100°. If the first temperature was 60°

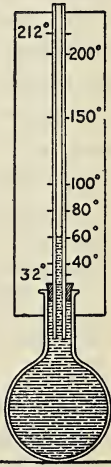


Fig. 72. A water thermometer

and the latter 100°, the space between the two bands represents the expansion due to a temperature change of 40°. Divide this space into 40 parts and we shall have a crude thermometer.

219. Water thermometer is not practical. Suppose that after making a water thermometer, you put it out of doors to see what the temperature is. If it is in the summer, this thermometer will answer very well; but suppose it is winter. How long would it be before the water would freeze and the thermometer break? Then, too, water expands in a curious way, as we shall see a little later. For these reasons water thermometers never are used practically. Instead, thermometers made of quicksilver, or mercury, which does not freeze so easily, are generally used. Sometimes alcohol is used for low temperature thermometers, because, while mercury freezes at 40° below zero, alcohol does not freeze until the temperature reaches 173° below zero.

Upon what principle does the working of a thermometer depend?
How could you construct a simple water thermometer?
Water thermometers are cheap. Why are they not used?
What two liquids are generally used in thermometers? Why?

220. Graduating thermometers. There are two temperatures that are easily obtained and are always the same. These are the *freezing point* and the *boiling point of water*. In graduating thermometers,

these two temperatures are used. First the thermometer is put into a cup filled with melting ice. The point to which the liquid in the thermometer sinks is named the *freezing point of water*, and is marked 32° F. Then the thermometer is put into steam from boiling water. The point to which the liquid rises is called the *boiling point of water*, and is marked 212° F. Knowing these two points, it is easy to mark the scale in degrees.

221. Fahrenheit. These two *fixed points* of the thermometer scale were used long ago by a Prussian, Dr. Gabriel D. Fahrenheit, and the scale in common use is named after him. There are other ways of graduating thermometers that are used in Europe. To distinguish the Fahrenheit thermometer readings, we usually put an "F" after the thermometer reading. We write the temperature of freezing water as 32° F.

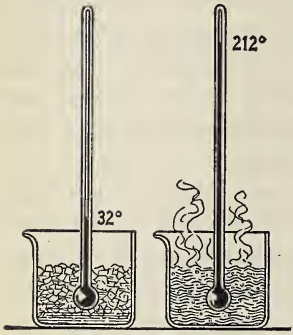
What are the two fixed points on a thermometer scale? How are they found?
Why do we call the common thermometer the Fahrenheit thermometer?
32° F. is the freezing point of what liquid?
30° F. below zero is how many Fahrenheit degrees from the boiling point of water?

Experiment 42

Question I: What is the melting point of ice?
Question II: What is the freezing point of water?
Question III: What is the boiling point of water?
Materials: Desk apparatus; thermometers; ice.

Directions: (*a*) Half fill a tumbler with finely crushed ice. Add enough water to make a mush. Stir with a thermometer. After two minutes read the temperature.

What is the melting point of ice? (This same temperature, 32° F., is the temperature at which water freezes. At 32° F. water will freeze or ice will melt, depending on whether we are adding heat or taking it away.)



Experiment 42

(*b*) Half fill a beaker with water and heat until it boils. When it is boiling gently, put the bulb of a thermometer in the water and read the temperature. *What is the boiling point of water?* Boil the water furiously and again take its temperature. Is the water any hotter than when it is boiling slowly?

Diagram: Show thermometer in beaker of ice and water and in boiling water.

Conclusion: Answer Questions I, II, and III.

Practical application: The temperature at which water boils is influenced by the pressure of the air. If you live at a high altitude — as near Denver, 5,000 feet above sea level — water will boil at a lower temperature than 212° F. In a steam boiler with a pressure inside of 250 pounds, water boils at 401° F. We should always say that water boils at 212° F. at sea level, or where the pressure is normal (usual).

CHAPTER TWENTY-EIGHT

CLIMATE AND THE BAROMETER

222. The air has weight. You learned last year that there is an attraction between the earth and other bodies, and that this attraction is called *weight.* You will remember the experiment in which we weighed the air in a basket ball. Air is matter, and, of course, has weight just as a stone has weight. It is hard to realize this, because air is a gas. Air, though, may be compressed or squeezed together and cooled until it turns into a clear liquid resembling, in appearance, water. It is easy to see that this liquid must have weight and that when it evaporates and turns back into a gas, it must have the same weight.

223. Dry ice. Dry ice is a familiar example of a gas that has been changed into a visible form. A lump of dry ice, which is solid carbon dioxide, may weigh one pound. If it evaporates, the gas produced will have the same weight, one pound.

224. How much does air weigh? Careful experiments have proved that twelve cubic feet of air weigh about one pound. Measure the classroom, find the number of cubic feet of air that it contains, divide this by 12, and the result will be the number

of pounds of air contained in the room. You may be astonished to find how much the air weighs.

Air has weight, because air is matter. You know that when you wade in water it is easy to move slowly, but it is impossible to run. You cannot push the water aside fast enough to gain much speed. Exactly the same thing is true with air. At slow speed you do not realize that there is anything in your way, but, as your speed increases, it becomes more and more difficult to push the air quickly out of your way. Put your hand out of the window of a swiftly moving automobile and you will feel this pressure of the air due to its weight.

Prove by an experiment that air is matter.
How much does the air in the science classroom weigh?
What is dry ice?
Why does doubling the horse power of an automobile not double the speed?

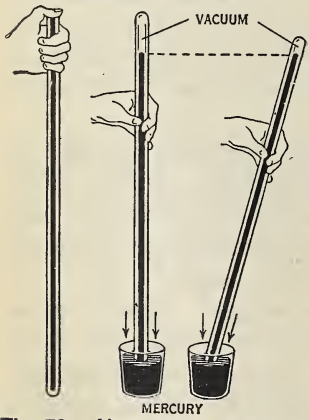


Fig. 73. Air pressure as shown by a barometer

225. The barometer. There are various ways of determining the amount of air pressure. The simplest way is to use a *barometer*.

Seal one end of a small glass tube that is about thirty-six inches long. Fill this tube with mercury,

put your finger over the open end, and invert the tube in a tumbler of mercury. Keep your finger over the end until you have placed the open end of the tube beneath the surface of the mercury in the tumbler. Then remove your finger (Fig. 73). Only a small amount of mercury runs out, and a column about thirty inches high remains in the tube. The pressure of the air on the mercury in the tumbler is holding the mercury in the tube.

Fig. 74. A mercurial barometer

This will perhaps be made clearer by examining the right-hand tube in Figure 73. Here a glass tube, tilted to the right, is used. The air is exerting a pressure on the mercury. The weight of the air, by pushing down on the surface of the mercury in the tumbler, holds the mercury in the tube to the same vertical height as in the upright tube. Anything that changes the weight of the air must change the height of the mercury column. That is, this tube, called a *barometer*, or better, a *mercurial barometer*, registers the weight of the air, or its *pressure* (Fig. 74).

How is a barometer constructed?
What is the use of a barometer?
Do you think that a water barometer might be made? Explain your answer.
Why does the height of a barometer change?

226. Barometer shows changes in air pressure. Look at Figure 75. A mercurial barometer has been put in a bottle, and by means of the tube A, it is possible to draw part of the air from the bottle. Place the tube in your mouth and draw out some air. The air pressure on the mercury in the bottle will be less, and the mercury in the tube will drop to a lower level, perhaps to B.

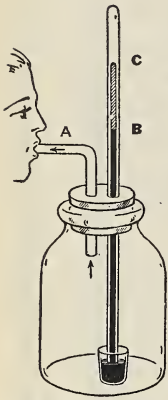


Fig. 75. A barometer in bottle to show air pressure changes

Blow into the mouthpiece, thus increasing the amount of air in the bottle. This increases the air pressure, so the mercury in the tube will rise, perhaps to the point C. This shows how the air pressure, which depends on the weight of the air, is measured by the barometer. We have found that at sea level the weight of a square column of air, one inch on each side (one square inch in cross section) and reaching from the earth to the top of the air, is about fifteen pounds. We call this pressure *one atmosphere.*

Describe an experiment to show how the height of the barometer changes as the air pressure changes.
What is meant by a pressure of one atmosphere?

CHAPTER TWENTY-NINE

AIR PRESSURE

227. We use air pressure. When we can fruit, we put a rubber ring between the top of the jar and the cover. Then, while the fruit is at the boiling point, and the steam has driven the air out of the jar, we clamp the cover on the jar (Fig. 76). As there is little or no air inside the jar, there is only a slight air pressure from the inside outward. If the top of the jar has a diameter of 2.5 inches, its area will be 4.9 square inches. (Area of circle = diameter squared $\times$ 0.7854.) The air pressure on the outside of the top of the jar will be 4.9 $\times$ 15 pounds equals 73.5 pounds. This explains why the cover clings so tightly. To remove it, pull out the rubber ring. This action admits the air to the inside of the jar. This equalizes the air pressure inside and outside and causes the cover to come off easily.

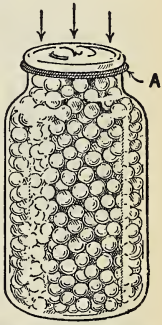


Fig. 76. Air pressure on a fruit-jar cover; A, rubber ring

228. Suction. There is really no such thing as "suction." When you draw on the straw in a glass of soda water you draw part of the air out of the

straw tube. The air pressure is then greater on the surface of the soda water in the glass outside of the tube than it is inside the tube, and the soda rises or, rather, is forced up into the tube by air pressure, just as the mercury is forced up into the barometer tube (Fig. 74).

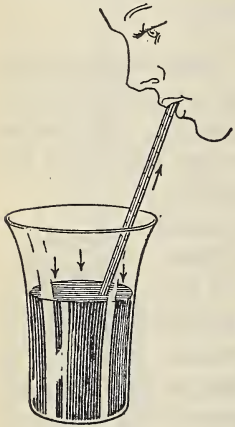


Fig. 77

Why does the cover remain on canned-fruit jars, even if not clamped on?
Why does pulling out the rubber ring make it easy to remove the cover of a fruit jar?
What really happens when we suck soda through a straw?

229. Water barometer. Any liquid may be used in a barometer. Mercury, however, is more practical to use because it does not require a long tube. This makes it easy to handle. Mercury is 13.6 times as heavy as water. A water barometer then must be 13.6 times as long as a mercury barometer; that is, about 34 feet long. If the school building were high enough, it might be worth while to make a water barometer. But water freezes at 32° F.; consequently do not try the experiment in the winter time.

230. Aneroid barometer. The mercury barometer is accurate, but it is not easy to carry and is easily broken. For these reasons a different form of

barometer is often used, called an *aneroid barometer*.

A metal box is made which has a very thin corrugated top (Fig. 78). Some of the air is pumped out of this box, and it is then sealed air tight. The metal that forms the top of the box is so thin that the air pressure pushes it in a little. As the air

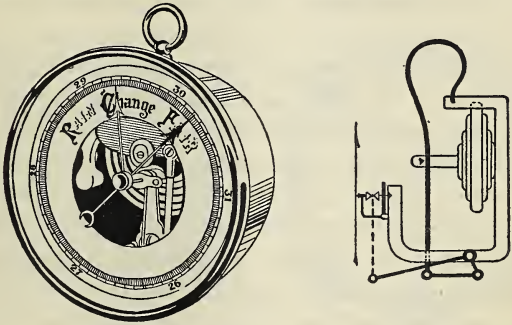


Fig. 78. A, the aneroid barometer; B, this shows you how a small in or out motion of the box of the aneroid is magnified, producing an extended motion of the pointer

pressure changes, the pressure on the top of the box changes, and the top of the box moves slightly in or out. This motion is too small to be seen, but by means of small levers or arms it is magnified. A hand or pointer is connected to these levers in such a way that as the top of the box moves in or out, the pointer moves over a scale. This scale is graduated or marked in inches by comparing it with the reading of a mercury barometer.

A second pointer is usually placed over the scale. This pointer is not connected to the air box, but may be moved to any point on the scale that we wish. If we wish to know whether the air pressure is increasing or diminishing, we place this second pointer over the hand of the barometer. Later we look at the barometer. The outside hand does not move unless we move it, while the barometer hand moves with every change in air pressure. The difference between the hand and the pointer tells us how much the pressure has changed, and in what direction.

231. Uses of the barometer. We shall see later that when the air pressure is diminishing and the mercury in the barometer is falling or going down, a storm is brewing. When the mercury is going up or rising, the air is heavier and the weather is clearing. Every weather station is therefore provided with a barometer.

How would you construct a water barometer? What would be one advantage of a water barometer? one disadvantage?
Explain the construction of an aneroid barometer.
What is the use of the second pointer on an aneroid barometer?
Why is it important to know whether a barometer is rising or falling?

232. Determining mountain heights. As one climbs mountains, one rises above part of the air. The air pressure is therefore less on mountain tops than it is at sea level. The higher the mountain, the

lower the barometer reading. A change of 90 feet causes a barometer drop of about 0.1 inch. At Denver, which is about 5,000 feet above sea level, the normal or usual barometer reading is about 24.5 inches.

233. How aviators determine altitude. The highest mountain in the world, Mt. Everest, has

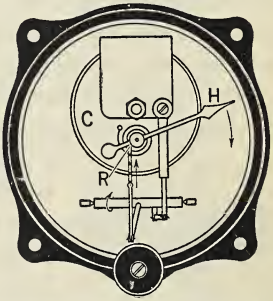


Fig. 79. The altimeter is really an aneroid barometer graduated for height instead of pressure. As the airplane climbs, the air pressure on the sealed box C decreases, and the box expands. By means of levers and a fine chain wound around the drum R, this motion is transmitted to the hand H

never been climbed. This is mainly because at this great height, 29,141 feet, there is not enough air to enable men to do the work of climbing. Aviators have flown to a height greater than that of Mt. Everest. This is possible because they carry with them a supply of compressed oxygen that is used to supplement the air which is so rare at high altitudes. Is it not wonderful how aviators determine

their altitude? They certainly cannot drop a plumb line, nor carry a yardstick with them. In reality, it is done very simply. The airplane carries a small aneroid barometer made in such a way that a pen traces the air pressure on a chart. As the airplane rises, the barometer falls, because the air pressure is less. When the plane returns to earth, the tracing on the chart tells the air pressure, and from a table the altitude is determined (Fig. 79.) Such special aneroids are called *altimeters*.

234. Weather vanes and wind cocks. While riding through the country we often see, on the tops of towers or the peaks of buildings, arrows, cows, horses, and roosters swinging in the breeze. They turn very easily on an upright rod or spindle. These turning objects are very useful. They show the direction from which the wind is blowing. At an airport a bag swings on a pole. These instruments are weather cocks or wind vanes (Fig. 80). We must remember that wind is always named for the direction from which it blows; thus, a *west wind* blows *from* the west.

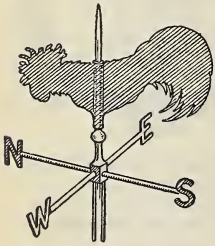


Fig. 80. A weather-cock

Why is the barometer reading at Denver lower than at Los Angeles?
Why has Mt. Everest never been climbed?
Why can aviators go higher than Mt. Everest?
How is the height to which an airplane rises determined?

What is an altimeter?

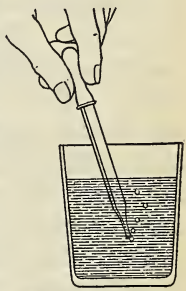
A wind blows toward the east. What is the name of the wind?

EXPERIMENT 43

Question: What causes ink to rise in a fountain-pen filler (medicine dropper)?

Materials: Glass of colored water; medicine dropper.

Directions: (*a*) Place the end of a medicine dropper under the surface of the colored water in a tumbler. Press the rubber bulb. 1. What do you see coming out of the end of the dropper? Release the pressure on the bulb and notice that water rises in the tube of the dropper. It would not rise unless something forced it up. 2. What is this something that forces the water up the tube? (Text, Sec. **225**.)



Experiment 43

(*b*) Place a straw in a glass of milk and "suck" on the end of the straw. Milk will come up into your mouth. 1. When you sucked on the end of the straw, what were you really doing? 2. Why did the milk rise in the straw? 3. If the straw had been *40 feet* long, could you have drawn up the milk into your mouth? Explain.

Diagram: Show the medicine dropper and the tumbler of water.

Conclusion: Answer the question.

Practical application: It is a difference in air pressures that causes winds and makes the barometer vary. If you have not tried inverting a glass of water and seeing that air pressure will keep the water in the tumbler (text, Sec. **287**), do so.

CHAPTER THIRTY

WINDS AND THE WEATHER

235. Air can dissolve water. When your father puts sugar in his coffee in the morning, it disappears. What has happened to the sugar? It has dissolved in the coffee. The hotter the coffee the more easily the sugar is dissolved. In the same way *air dissolves water*. When air has dissolved all the water that it can at any given temperature, it is a *saturated solution*. If the air is heated, it can dissolve more water, but there comes a time when even hot air can dissolve no more, or is *saturated* with water.

236. Fog or cloud. This invisible dissolved water is called *water vapor*. It is always present in the air. If a saturated solution of water in hot air is cooled, the cool air cannot dissolve so much water as did the hot air. The excess water then separates into tiny drops. This causes a *fog* or *mist*. If it occurs high up in the sky, we call the mist a *cloud*.

237. Humidity. The condition of the air, due to the water dissolved in it, is called *humidity*. To say that the "humidity is high" is the same thing as saying that the air contains a great deal of water vapor. Relative humidity is the ratio between the amount of water actually present in the air and the

amount of water required to saturate the air. At 70° F., a cubic foot of air will dissolve 8 grains of water. It is then saturated. Suppose that at 70° F. a cubic foot of air actually contains only 4 grains of water. It will be $\frac{4}{8}$, or half, saturated; that is, it will be 50 per cent saturated, or, the relative humidity will be 50 per cent.

Why does fog form? Why does it disappear?
Define the terms *mist, fog, cloud.* Why do they form and disappear? Why does it rain?
What is humidity? Define *relative humidity.*
Why does the Weather Bureau determine the humidity daily?

238. Too high and too low humidity. When the relative humidity is low, the mucous membranes of the nose and throat become very dry, and one feels very uncomfortable. The air is thirsty and takes water from everything. Such a condition is undesirable and can be prevented only by supplying more water to the air. Some people do this by hanging wet towels in the room or by hanging cans of water behind the radiators.

Too high a relative humidity also makes us uncomfortable, especially in summer. When the air is saturated with water vapor, perspiration cannot evaporate and we feel hot and sticky. Such days we call *humid.* A temperature of 90° F. in Arizona may be more bearable than a temperature of 80° F. in New York, because of the much lower relative humidity there.

The people of Ireland are noted for their fine complexions. The people of Egypt often have dry, leathery skins. The relative humidity of Ireland is high, of Egypt low. Can you explain the connection between these facts?

Why is a very low relative humidity objectionable? a very high relative humidity?
How may a low relative humidity in our homes be remedied?
Why does your throat often feel dry when you are in a steam-heated apartment?

239. Precipitation. When air is compressed, heat is developed. If you have ever pumped up an automobile tire, you know how hot the pump becomes. When air expands, the reverse change occurs, and the air is cooled. When air rises, it expands and becomes cooler. If the relative humidity of the air is high, this cooling will cause the air to be more than saturated and water will form in small drops, as a *fog* or *cloud*. As the process of condensation continues, the drops grow larger, and it rains. If the temperature of the cloud is below 32° F., the water vapor condenses into *snow* instead of rain. If rain freezes as it falls it becomes *hail*.

240. Dew. When the earth cools at night, and the humidity is high, water is deposited on the earth as *dew*. If the temperature of the earth is below 32° F., the water is deposited as *frost*.

Dew may be formed by breathing on a cold window-pane. The warm moisture-laden breath is cooled

and some of the moisture it contains condenses on the windowpane. If the temperature of the windowpane is below 32° F., frost will form on the window instead of dew.

Explain the formation of rain, snow, hail, dew, frost, clouds, and mist.
Does dew really "fall"? Explain.
Why do pitchers of ice water "sweat"?

241. Winds. You have learned that heat causes things to expand. When air in any region is heated,

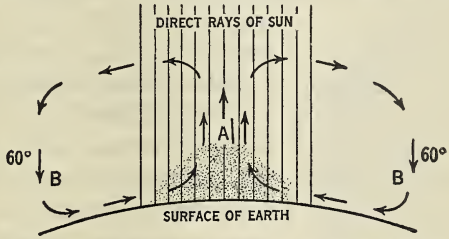


Fig. 81. The cause of winds. A, area of high temperature and ascending air currents; B, area of cool temperature and descending air currents

it expands, becomes lighter, and rises, causing a diminished air pressure in that particular locality.

242. Circulation of air. Over the equator, the sun's rays pour down vertically. This heats the air, causing it to expand and creating a diminished air pressure at that point. From north and south of the equator the cooler air, because of greater pressure, pushes in to take the place of the warm air, and a circulation of air is produced (Fig. 81).

243. Winds and currents. Near the surface of the ground, the cool air moves from the north and the south toward the equator. Far above the ground the hot air moves away from the equator to the north and south. We call the air movement near the earth a *wind.* The upper air movement we call a *current.*

A wind of 4 m.p.h. (miles per hour) is a gentle breeze; 10 m.p.h., a pleasant breeze; 30 m.p.h., a high wind; 30 to 75 m.p.h., a gale; over 75 m.p.h., a hurricane.

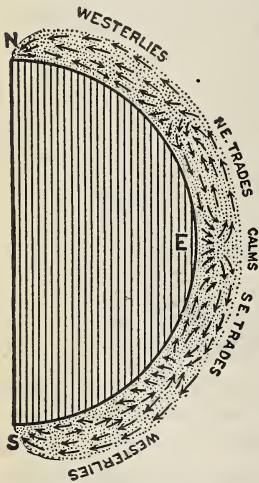


Fig. 82. A cross section of one half of the earth and its atmosphere. The atmosphere is much exaggerated in height so that the arrows can show the direction of the air on the earth and above it

244. Storm areas, general. The atmosphere is in constant motion, because of its changing temperature and pressure. Since some parts of the torrid zone are always receiving the vertical rays of the sun, the air becomes heated and, consequently, rises, being replaced by cooler air that pushes in from the north and south. The *doldrums* are the heated belt or zones from which the hot air rises. They are regions of high temperature, light winds, and heavy rainfall. The days vary little in length.

245. Trade winds. The *trade winds* are the cooler winds that come in to take the place of the hot air of the doldrums. The trades, because of the rotation of the earth, do not blow directly north or south, but are turned somewhat to the west. This region has little rainfall. Its marked characteristic is the *constancy of the winds*. They blow winter and summer, day and night, toward the doldrums belt (Fig. 82).

These facts are only general statements. Weather conditions are modified by local causes.

What are the doldrums? Where are they?
Why is there a heavy rainfall at the equator?
What causes the trade winds?

246. Lows: cyclones. When an area of *low pressure* develops, the lighter air at the center is pushed up by the heavier, cooler air flowing in from all directions toward the center area of low pressure. Owing to the rotation of the earth, this flow of air or wind is changed into a great whirl of air flowing in the United States in a counterclockwise direction. This kind of eddy is called a *low* or *cyclone* (Fig. 83). The word "cyclone" means "whirling."

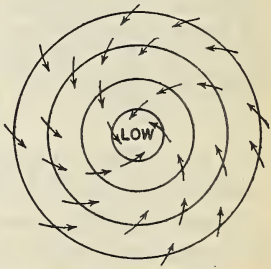


Fig. 83. The low or cyclone. Air rises within the central area of the low, and gives to the inflowing air currents the effect of a spirally upward motion

The winds that push in from all sides toward the center of low pressure have no place to go except upward. As this air rises, it expands, cools, and its moisture is precipitated as clouds and rain. A *low*, therefore, means *rainy weather*.

247. Highs: anticyclones. When an area of *high pressure* develops, at its center is a column of cold, heavy, descending air. This heavy air pushes out from the center in all directions, forming an eddy similar to a cyclone, but with the wind blowing *away from the center*. This is a *high* or an *anticyclone* (Fig. 84).

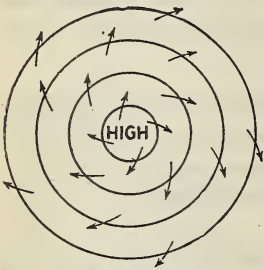
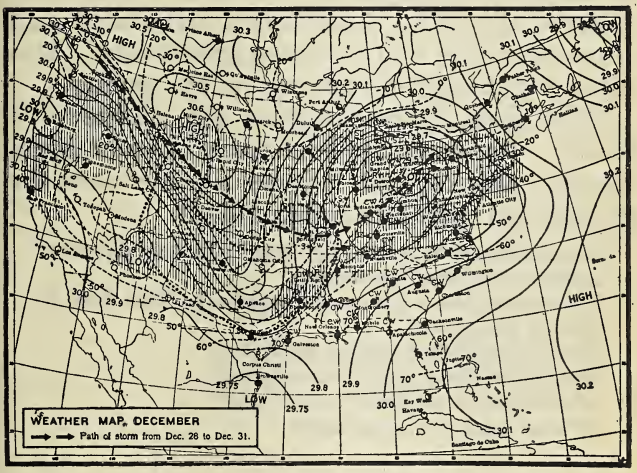


Fig. 84. The high or anticyclone. The air masses settle down within the central area of a high and flow spirally outward at the surface, giving the effect of spirally descending air currents

The descending, cool, heavy air at the center of a high contains little moisture, and as it blows away from the center, it becomes warmer, and its ability to dissolve water increases. A high, therefore, means clear weather.

These whirling masses of air, "highs" and "lows," or "cyclones" and "anticyclones," are sometimes hundreds of miles in diameter. They pass in succession over our country from west to east. Storms which were over Chicago yesterday are very likely to be over New York City today.

248. Weather maps. Watching Mother Nature regulate the weather is a good hobby to cultivate. Tomorrow's weather is being made today, as you will find if you will study the daily weather map. Studying one map is useless; you must study them



Courtesy U. S. Weather Bureau

Fig. 85. A typical weather map issued by the Weather Bureau

day after day if you are going to be able to trace the path of storms over our land. A typical map is shown in Figure 85.

249. Hot waves. When a low moves with unusual slowness, the water vapor at its center may become exhausted, almost all of it having fallen as

rain. This causes a *hot wave* that lasts until the low is finally driven forward by a high.

250. Cold waves. A slow-moving high may in winter blanket the country with a mass of cold, heavy air. This remains in place until sufficiently warmed by the sun to rise and to be followed by a low. This causes a *cold spell.* Sometimes a pronounced high brings down very cold air from a great height. This causes a *cold wave* that moves over the country.

Many local factors influence the climate of a locality. Its nearness to large bodies of water, ocean currents, altitude, and latitude all enter into the problem and make forecasting difficult.

What is meant by a low or cyclone? In what direction do they travel over the country?
What effect has a low on the weather? Why does it produce this effect?
What is meant by a high or anticyclone?
What effect has a high on the weather?
What causes a hot wave? a cold wave?
Of what use is a weather map?

Experiment 44

Question: Of what use is a weather map?

Materials: Weather maps.

Directions: Your school is doubtless provided with a daily weather map issued by the United States Weather Bureau. These are free to schools. Your science teacher will pin up the maps for a week or more, so that you may examine them.

Look at the first map and learn what all the symbols mean. You will find an explanation of them on the map. When you

think that you know them, have a comrade cover the explanation and ask you the meaning of the various signs.

Begin with the first map and pick out in the west a "low" with rain. Trace the progress of this low on the daily maps as it moves eastward over the country until it disappears over the Atlantic Ocean. In the same way trace the progress of a "high." It is a good plan to make an outline map of the United States on the blackboard and mark on it the position of the "low" for each day. Connect these points and you will have the path of the storm.

Notice the direction of the whirl of air around the low and around the high. In a storm area, in a low, the air is moving in a spiral toward the center, while in a high the air is whirling outward.

If there is a Weather Bureau Station in your city, ask your science teacher if he will not make an arrangement with the observer, so that you may visit the Weather Bureau and learn how its work is carried on. You will find the observer using thermometers, a barometer, and a hygrometer very similar to the instruments that you have used in your laboratory work.

Diagram: Draw an outline map of the United States. Mark on it the position of a typical high and a typical low. Draw arrows to show the direction of the winds around each.

Conclusion: Answer the question.

CHAPTER THIRTY-ONE

ENERGY AND ITS TRANSFORMATIONS

251. Our world of energy. If you will think over the work that you have been doing in science, you will see that you have really been studying *action* or *work*. Our environment has been studied while it was in motion. Water has dropped in waterfalls, wind has moved the branches of trees, or, when very strong, has even moved the trees themselves. Planets are moving in the heavens. We give a name to this something that gets things done. We call it *energy*.

252. Energy defined. We define energy as *the power to do work*. The sun has energy because it has power to do work. Sunlight can make plants grow, or it can evaporate water which later falls as rain. Sunlight, too, furnishes the light and heat that keeps us alive and well. Coal, too, has energy. When it is burned, its energy enables the steam engine to do work. We ourselves have energy because we have the power to do work.

Define energy.
Why do we say that we have energy?
How do you know that coal has energy?
Does gunpowder have energy? Does gasoline? Explain.

253. What work is. Before talking about energy, we should have a clear idea of just what scientific men mean by the word *work*. It is not quite the same thing as labor. By work we mean *the moving of a a body against some resistance*. When we lift a stone, we are doing work, for we are moving the stone and overcoming the force of gravity. When we run upstairs, our muscles are doing work, because they are causing motion in opposition to the force of gravity. Remember that in the scientific meaning of work *there must be motion*.

Define work.
Name some work that you have done today and explain why you call it work. What do you have that enables you to do this work?

254. Conservation of energy. We might say that the study of science is the study of energy, its forms and changes. These changes of energy from one form to another we call *transformations of energy*. They are so common that one can think of many of them. For instance, sunlight causes grass to grow, and the energy of the sun is changed into the chemical energy contained in the many compounds found in grass. A cow eats the grass, and, because of the energy possessed by her digestive juices, the energy of the grass is changed by the cow into muscle. We eat a steak and the energy of the cow's muscle is changed into the energy of our own muscle. We run a race and our muscular energy is changed into

heat and motion. In all these transformations of energy, *the total amount of energy is not altered, only its form changes.* This fact is known as the Law of the Conservation of Energy. This is usually stated as, *Energy can neither be created nor destroyed.* This is one of the fundamental laws of nature.

255. Sources of energy. Our great source of energy is the sun. It furnishes heat, light, and chemical energy. Coal is another source of energy, but since coal is nothing but the remains of trees and other plants that grew in past ages, the energy of coal is really the sun's energy stored up in a lasting form.

256. Body energy. Our bodies have energy. This energy comes from the food that we eat, and this in turn represents the sun's energy, for without the sun's light and heat vegetation could not grow. In the end, then, we see that *most of our energy comes from the sun.* Is it any wonder that ancient people worshiped the sun as a god?

From your own experience, give an example of the transformation of energy.
State the law of the conservation of energy.
Give, as far as you can, all the energy transformations involved between a waterfall and a loaf of bread.
What is our main source of energy?
What is the real source of our bodily energy?
Explain your answers in detail.

257. Two kinds of energy. Potential. All energy is the same, for it can do work. It is convenient,

though, to divide energy into two classes. Water on the surface of the earth apparently has no energy, because it does no work. If it be lifted to a height, it is given energy, because if allowed to fall it will set a water wheel in motion; that is, it can do work. Water high above the surface of the earth has energy because of its *position*. We call such energy *potential*, or stored-up, energy.

A shade roller spring when wound up has potential energy, because it can cause the window shade to move upward, or it can do work. Its energy is potential, because it depends on the position we gave to the coils of the spring when we pulled the shade down.

258. Kinetic energy. A moving automobile has energy, while an automobile at rest has none. It can do work only when it is in motion. This *energy of motion* we call *kinetic energy*. A moving bullet can pierce a thick plank. It has energy of motion, or kinetic energy. Before the gun is fired, this energy exists as the chemical energy of gunpowder, or potential energy. When the bullet strikes the plank, its kinetic energy is changed into heat energy and passes off into the air, or is used in heating the plank.

259. All energy is one. A swinging pendulum ball is an excellent example of the exchange between potential and kinetic energy. When the pendulum is at the end of its swing, the ball is at its highest

point and for an instant is at rest (Fig. 86). Its energy at this time is all *potential.* As it starts to swing back, the ball moves faster and faster, until it reaches the middle point of its swing, when it is at its lowest point and is moving its fastest. Its energy is now all *kinetic.* Then it swings past the middle point and finally comes to rest at the opposite end of its swing. Its energy is now once more all potential. At any point in its swing, however, *the sum of its potential and kinetic energy is the same.*

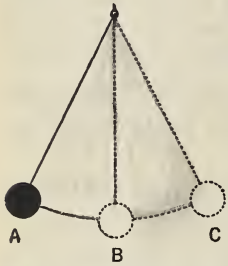


Fig. 86. Pendulum ball showing exchange of potential and kinetic energy. A, all potential; B, all kinetic

Define potential energy. Give two examples.
Define kinetic energy. Give two examples.
Why do we say that an electric fan has energy?
What kind of energy does it possess?
How does a pendulum ball illustrate a change from one kind of energy to another?

CHAPTER THIRTY-TWO

LEVERS

260. The machine age. Our present age is sometimes called the age of machines. When we think of washing machines, flying machines, and machine shops, our age seems well named. When we ride in an automobile, and think of its engine, transmission, differential, bearings, and all the other parts that seem so complicated, we wonder that any one person can understand it all. Wheels, shafts, engine, all appear to move in mysterious ways. It seems very hard to understand what makes the wheels go around.

261. All machinery depends on principles. Yet the principles used in building an automobile are few and simple. In fact, all machinery depends on only a few simple principles, and it is by combining these simple principles that the more complex machines are made to work. To understand the operation of these seemingly very complicated machines, it is only necessary to understand the simple machines of which these compound machines are composed. The engines that drive the steamship *Leviathan* over the ocean, or that turn the printing press that prints, cuts, folds, and stacks in neatly numbered piles our

daily newspaper, are examples of such compound machines.

262. A simple machine: the lever. The simple machine that we study first is the *lever*, crowbar, or pry. Balance a ruler on a pencil (Fig. 87). We call such a device a *lever*, and the point on which it balances a *fulcrum*. Put a two-ounce weight on one

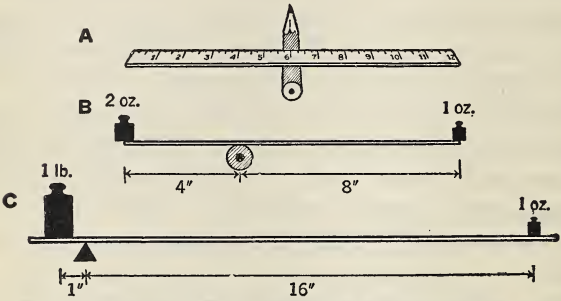


Fig. 87. Levers: Effort times effort arm equals resistance times resistance arm

end of the ruler and a one-ounce weight on the other end. You will find that the ruler no longer balances on the fulcrum. Roll the pencil until you find a point where the ruler once more balances. You will discover that the fulcrum must be nearer to the two-ounce than to the one-ounce weight (Fig. 87). Since the one-ounce weight can balance the two-ounce weight, we have seemingly overcome the law of the Conservation of Energy. We seem to be

doing a great deal of work with the expenditure of a very little energy.

Think again, though. Look at the distances that the two weights move. You will see that the one-ounce weight moves twice as far as does the two-ounce weight. In reality we have exchanged moving a one-ounce weight two inches for moving a two-ounce weight one inch.

263. Use of levers. Try using a one-pound weight and a one-ounce weight. You will find that if the pound weight is one inch from the fulcrum, the one-ounce weight must be sixteen inches from the fulcrum when the lever balances (Fig. 87). When the pound weight moves up one inch, the ounce weight moves down sixteen inches, and our law of energy holds true. Every child is familiar with these facts. We all know that on a seesaw a big boy must be nearer the fulcrum than a small child must be, if the seesaw is to balance.

In a lever, then, we really *gain no energy*. We *exchange* moving a light weight a long distance for moving a heavy weight a short distance. You can readily see how a lever can be used to move heavy stones and do similar toilsome work (Fig. 88).

Fig. 88. A crowbar in use

264. Law of the lever. It makes this clearer if we call the weight that we wish to move the *resistance* and the weight that we use to move it, the *effort*. We may then say: Resistance times distance it moves equals effort times distance it moves. It is also true when the lever balances, that the effort multiplied by its distance from the fulcrum will always equal the resistance multiplied by its distance from the fulcrum. Resistance times its distance from fulcrum equals effort times its distance from fulcrum.

265. Seesaw lever. The advantage of stating our facts in such a form as that given in the last part of the previous paragraph is that it makes them easy to remember and also makes it easy to solve lever problems. For example, two children wish to use a seesaw. (See Fig. 89.) One child weighs 100 pounds and is seated 4 feet from the fulcrum. The other child weighs 50 pounds. How far from the fulcrum must he be seated to balance the seesaw? The answer must be eight feet, for then

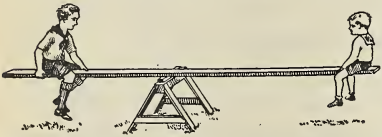


Fig. 89. A seesaw. Why does the heavier child not sit at the end of the plank?

$$\underbrace{100 \times 4}_{400} = \underbrace{50 \times 8}_{400}$$

Why do we call this the age of machinery?

In a lever, what do we mean by the fulcrum, the effort, and the resistance?

What is the law of the lever?
A boy weighs 75 pounds and a girl weighs the same. They wish to use a seesaw. If the fulcrum is placed in the middle of the seesaw and the children at the ends of the plank, will the seesaw balance? Explain the reason for your answer. (See Fig. 89.)
In the last question, the girl is replaced by a man weighing 150 pounds. Where must the fulcrum now be placed if the seesaw is to balance? Make diagrams to illustrate your last two answers. Will the man or the girl have the longer ride on this seesaw?
Draw a diagram to show how you would place a crowbar so that you could move a heavy stone.

266. Useful levers. Many common household tools and utensils are levers. Pick up your mother's scissors and study them, thinking of them as levers. The fulcrum is the screw holding the two parts together. Your hand supplies the effort and the cloth to be cut supplies the resistance. If the cloth is difficult to cut, you bring it near the fulcrum, because the nearer the resistance is to the fulcrum the easier it is for a small force moving a considerable distance to overcome it (Fig. 90).

Fig. 90. Scissors. Where is the fulcrum?

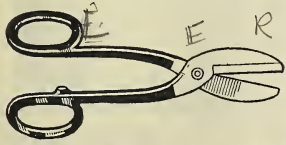


Fig. 91. Tin snips. Where are the fulcrum, effort arm, and resistance arm?

267. Cutting tin with scissors. It would be difficult to cut tin with ordinary scissors, for the resistance

would be too great. The handle of the tin-cutting scissors are, therefore, made long so that a small effort may be applied through a long distance (Fig. 91).

268. Effort and resistance. Not all levers have their fulcrums between the effort and the resistance. How many of you have ever thought of sugar tongs and grass snips (Fig. 92) as levers? Yet that is exactly what they are. These levers, however, have the fulcrum at the end. You can easily understand why levers of this sort are used for things like sugar tongs and grass snips. They are used where the resistance is small. The lump of sugar is light, and the grass is soft and much easier to cut than a piece of tin or heavy cloth.

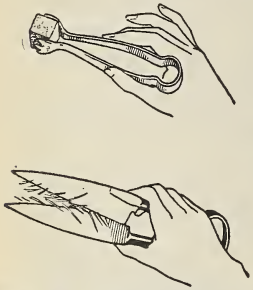


Fig. 92. Sugar tongs and grass snips. Where is the fulcrum?

269. Levers in our bodies. Your own forearm is a lever. The muscle of the upper arm is attached to a point near the elbow (Fig. 93). By contracting this muscle, you can raise your hand and lift a weight. In this case the elbow joint is the fulcrum, the muscle supplies the effort, and the resistance is the weight in your

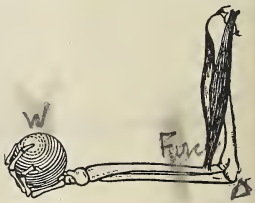


Fig. 93. The forearm acts as a lever. Find the fulcrum, effort arm, and resistance arm

3rd

hand that is to be lifted. The nearer to your elbow that you can place the weight, the heavier the weight you can lift.

In the questions below, use a diagram to make your answers clear.

Show how a pair of scissors is really a lever.
Why are tin snips made with long handles?
Why are paper shears made with long blades?
Name a lever where the fulcrum is at the end, and show by a diagram that it is a lever.
In using a nutcracker, where would you put a nut that was hard to crack? a nut that was easy to crack?
Make a diagram of a wheelbarrow and name on it the parts of a lever.

Experiment 45

Question: What is the law of the lever?

Materials: Small piece of wood, cut in a triangular shape for use as a fulcrum; a 2-foot ruler; 16-, 8-, and 4-ounce weights.

Directions: (*a*) Place the ruler on the fulcrum and slide it along until it just balances. You will find that the 12-inch mark is just over the fulcrum.

(*b*) Place the center of the 8-ounce weight (call this weight the *effort* E) just over the 2-inch mark on the ruler. Slide the 16-ounce weight along the ruler on the opposite side of the fulcrum until the ruler just balances. (Call the 16-ounce weight the *resistance* R.) You will find that R must be placed just over the 17-inch mark. Calculate the distance of E and R from the fulcrum. Record all your results in the table. Call the distance of E from the fulcrum, D_e. Call the distance of R from the fulcrum, D_r.

Table

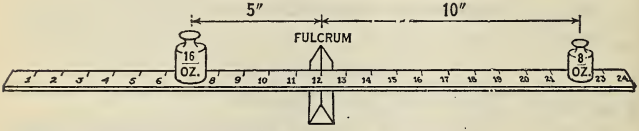
To make the ruler balance when the 8-ounce weight E was ..... inches from the fulcrum, I had to put the 16-ounce weight

R ..... inches from the fulcrum. E = ... ounces. D_e = ... inches. R = ... ounces. D_r = ... inches.

(*c*) Multiply E by D_e. Multiply R by D_r. Notice that you obtain the same result in both cases. This fact is always true and is known as the *Law of the Lever*.

(*d*) To confirm your result. Place the 4-ounce weight 10 inches from the fulcrum and calculate, using the law you have just found, where you must put the 8-ounce weight to balance the lever. Place the 8-ounce weight on the calculated position and see that the lever really does balance.

In this experiment, pay no attention to the weight of the ruler. It is also difficult to place the weights exactly over the



Experiment 45

proper marks. For these reasons your results may not be exact. If you repeat them a number of times and take the average of the results, you will find that the law is true. The better your apparatus, and the more care you use in carrying out the directions, the more nearly you will come to the exact law.

Diagram: Show the ruler balanced on the fulcrum and two weights in position. Be sure to mark weights and distances properly.

Conclusion: Answer the question. (See text, Sec. **264**.)

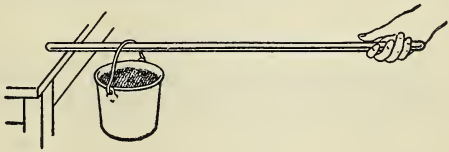
Practical application: 1. To move a heavy stone, using a heavy bar as a lever, should the fulcrum be placed close to your hand or close to the stone? Why? 2. Explain how an ordinary equal-arm balance illustrates the law of the lever. (Your teacher will show you such a balance.)

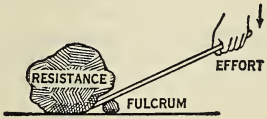
EXPERIMENT 46

Question: What are some of the advantages of a lever?

Materials: A strong stick 4 feet long; a heavy weight such as a small pail of dirt, earth, soil; a table.

Directions: (*a*) Place the stick through the handle of the pail. Rest one end of the stick on the table, and slide the pail close to this end. Support the other end of the stick in your hand. (See diagram.) 1. Does it seem as if you were supporting a heavy weight? Slide the pail along the stick nearer and nearer to your hand. 2. How does this seem to change the weight you are supporting?





Experiment 46

The table is the fulcrum (see Sec. 262 of text), the distance from your hand to the table is the length of the lever arm that we call the *effort arm* (D_e). Your hand supplies the effort required to balance the weight of the pail. The weight of the pail is the resistance to be overcome, and its distance from the fulcrum is the distance arm (D_r). 1. To support a heavy weight, should D_e be large or small? should D_r be large or small? 2. In using a crowbar, why do we place a stone close to the end of the crowbar and close to the heavy weight we wish to move? (See diagram.)

(*b*) Place the pail close to the table. Move your hand up and down a foot or more. Notice how much the pail moves. You will see that you have exchanged moving a heavy weight a short distance for moving a small effort a large distance. How do the distances which your hand and the pail move compare?

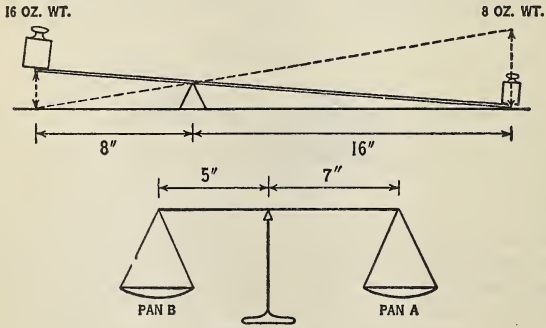
Diagram: Show the pail and stick in position.

Conclusion: 1. Give two advantages of the use of a lever. 2. Show by a diagram how you could use a lever to move a heavy stone.

Practical application Levers are used in moving heavy weights, in balances, and in moving a large resistance by a small effort.

Experiment 47

Question: I learned that energy can neither be created nor destroyed. With a lever, I can lift a 16-ounce weight, using



Experiment 47

only an 8-ounce effort. Does this not contradict what I learned about energy?

Materials: A 2-foot ruler; 8- and 16-ounce weights; a fulcrum; a 1-foot ruler.

Directions: (*a*) Put the ruler on the fulcrum, the 8-ounce weight (call this weight *E*) at one end and the 16-ounce weight (call this weight *R*) at the other end. Slide the ruler along on the fulcrum until it balances.

(*b*) Taking care to avoid changing the position of the lever on the fulcrum, press the end carrying the 8-ounce weight E to the table. Measure the distance the 16-ounce weight R is from the table. Record the result in the table.

(*c*) Press the end carrying the 16-ounce weight R to the table. Measure the distance the 8-ounce weight E is from the table. Record the result.

TABLE

The ruler balanced when the fulcrum was at the ..... inch mark. When E is at the table level R is ..... inches from the table. When R is at the table level E is ..... inches from the table. The weight E (8 oz.) therefore moves ..... inches while the weight R (16 oz.) is moving ..... inches.

(*d*) Multiply E by the distance it moves. Multiply R by the distance it moves. Your results should be the same, showing that the law of energy has *not* been proved untrue. What you have gained by being able to move a large weight with a small one, you have lost by having to move the smaller weight a longer distance. This is always true in machines. We can get nothing more out of the machine than we put in, but we can exchange moving a large resistance a short distance for moving a small effort a large distance.

Diagram: Show the arrangement of the lever and weights.

Conclusion: Answer the question, and explain how your answer is arrived at.

Practical application: A cheat made a balance having the fulcrum placed so that one arm A of the balance was 7 inches long and the other end B was only 5 inches long. When he bought, he placed the goods on one pan, and when he sold, he placed the goods on the other pan. 1. Did he use pan A or B for goods to be sold? If you wish to do so, you can calculate

just how much he cheated, for, if you will think over Experiment **45**, you will see that a 7-pound weight in pan B will just balance a 5-pound weight in pan A. 2. If you bought 10 pounds of butter (real weight) at 50 cents a pound, what did the butter seem to weigh, and what was the overcharge?

In the case above, the difference in the length of the arms is so great that you would notice it. If the difference is made small you would not see it, but the grocer or butcher would be giving short weight all the time. To prevent this, balances are tested by the government and *sealed.* That is, they are stamped, in proof that they give an honest weight. Look at the next scale that you see and find the mark of the sealer.

NOTE: The law of the lever is true, whether the lever bar is straight or not. A claw hammer used to pull out a nail is a lever. Draw a diagram to illustrate its action and you will see that the lever in this case is not straight, but bent. In the same way, a crowbar may have a decided bend in it. In all these cases, remember that you must measure in a straight line from the fulcrum to the points where effort and resistance are applied.

In all practical problems, the weight of the lever bar must be taken into account. To tell you how to do this would carry us too far into the study of physics. Remember, though, that all your experimental results would be more accurate if we did take into account the weight of the bar that you use as a lever.

CHAPTER THIRTY-THREE

SIMPLE MACHINES

270. Pulleys. The *pulley* is a simple machine. It is a grooved wheel supported in such a way that the wheel turns freely. A rope passes over the groove as shown in Figure 94. The next time you pass a building that is being erected, you will probably see many pulleys in use. The wheel may have several grooves in it, so that by using two pulleys we can get such combinations as those given in Figure 96.

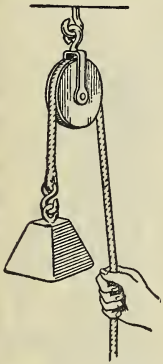


Fig. 94. A pulley can change the direction of motion

271. Work of pulleys. One simple use of a pulley is to change the direction of a pull. A weight is to be lifted from the ground. Such an arrangement as that shown in Figure 94 makes it possible to pull *down* while the weight moves *up*. In this case, nothing is gained by the pulley except that the direction of motion is changed.

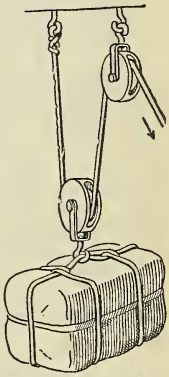


Fig. 95. A 50-pound pull can lift 100 pounds

272. Advantage of pulleys. By changing the way in which the pulley is attached, it can be made to lift a 100-pound weight by using an effort of only 50 pounds. Here, for every two feet of rope that is pulled, the weight goes up only one foot. The 100-pound weight is moved by an effort of 50 pounds, but moves only one foot to every two feet that the effort moves. Here again we have merely changed moving a heavy resistance slowly to moving a smaller effort more rapidly (Fig. 95).

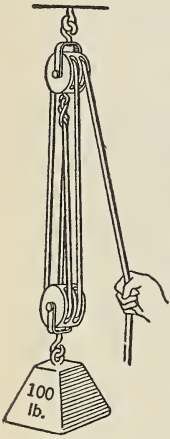


Fig. 96. A combination of pulleys. What pull will be required to lift the 100 pound weight?

Remember the lever formula. Effort times the distance it moves, equals resistance times the distance it moves. This same formula is true for pulleys. The reason why you were asked to learn this formula is because it will help to solve all kinds of problems about machines.

Fig. 97. A multiple pulley. Count the ropes supporting the weight and calculate the pull required to lift 100 pounds

273. Lifting weights. Sometimes we wish to lift very large weights without using very great effort. A com-

bination of two pulleys is used, both wheels having a number of grooves. In Figure 97 such a combination is shown. If you will study the figure, you will see that, since there are six ropes between the two pulleys, all of which are shortened when the weight is lifted, it will be necessary to pull the rope marked *effort* six feet to raise the weight one foot. Here again the formula is true. If the weight is 600 pounds, it will be lifted by pulling 100 pounds, but it must be pulled six feet to lift the weight one foot, or, $600 \times 1 = 100 \times 6$. If, then, it is desired to lift 300 pounds with this arrangement of pulleys the equation will be $300 \times 1 = \text{effort} \times 6$. The effort, then, must be 50 pounds.

Always use diagrams in answering questions on machines. It makes the explanation clearer and more understandable.

Explain the construction of a pulley.
Draw a set of pulleys so arranged that an effort of 50 pounds will lift a weight of 250 pounds.
A weight of 1,000 pounds is attached to a set of pulleys. When the weight rises one foot, the effort rope is pulled in 20 feet. What effort was used?

274. Wheel and axle. The wheel and axle, by means of which a bucket of water is lifted from a well, is another machine that is really nothing more than a lever. Study Figure 98. When the handle has made one complete turn, the rope has been wound around the axle once. If the length of the

circumference of the circle that the handle moves through in making one turn is 6 feet and the length of the rope wound around the axle is 1 foot, then the effort has moved 6 feet and the resistance has moved 1 foot. Once more using the lever formula, it may be shown that if the bucket of water weighs 60 pounds it can be lifted by using an effort of 10 pounds on the handle. Moving a large weight through a short distance has been exchanged for moving a smaller effort through a longer distance.

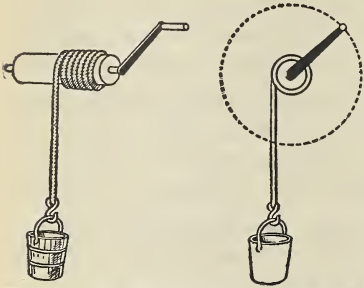


Fig. 98. Wheel and axle. The length of the crank handle determines the advantage

275. The capstan. A capstan is an upright revolving drum or cylinder used on ships for a similar purpose (Fig. 99). As the sailors push the capstan bars around, the anchor comes up from the bottom. By using several long bars, and a small post on which to wind the anchor rope, it is possible to raise very heavy anchors.

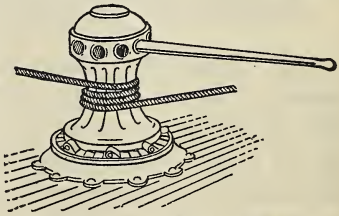


Fig. 99. A ship's capstan

The steering wheel of an automobile is a similar device. Examine it and you will see that the hands supply the effort while the friction of the wheel on the ground supplies the resistance. The larger the wheel, the more easily it turns.

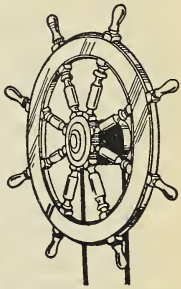


Fig. 100. Steering wheel of boat. What is the relation between the size of the wheel and the ease of steering?

A boy must draw water from a well. He finds that it is hard for him to lift a full bucket of water. What can be done to help him?
How is a ship's anchor raised?
Why are long handlebars on a bicycle an advantage?
Make a plan for turning the rudder of a boat, using a wheel and axle and pulleys for changing the direction of the pull (Fig. 100).

276. Inclined plane: skids. It often happens that truckmen need to place a case or a barrel in a truck. It is too heavy to be lifted directly. The truckman then places *skids* on the back of his truck (Fig. 101). Examine the figure and you will see that once more we are using the principle of the lever. We are moving a barrel weighing perhaps 400 pounds up an incline that is eight feet long. While rolling the barrel along the skid, it is lifted two feet. For

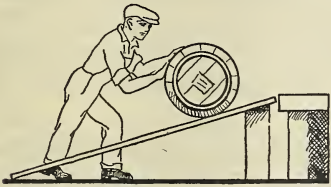


Fig. 101. Inclined plane

every foot that the barrel is lifted the effort is applied for four feet. Once more an exchange is made of moving a heavy resistance a short distance for moving a small effort a long distance. The longer the skids are, the longer the distance through which the barrel must be rolled, but the easier the roll will be. Such a device is often called an *inclined plane.*

What is meant by skids?
If you had to roll heavy barrels into a truck, would you use long or short skids? Why?
If your skids were 10 feet long, and the back of the truck was 2 feet above the ground, what effort would be required to lift a barrel weighing 500 pounds into the truck?

277. Friction not counted. In the chapter on levers, no account was taken of the weight of the lever. To do this would complicate the problem. When you come to the study of physics, you will learn how to include this lever weight in problems. Also with pulleys, we did not take into account the friction of the wheel. For these and similar reasons, a simple machine is never quite so useful as the formula makes it appear. The difference is not great, but it must be remembered that it exists.

278. Efficiency. One word often used is *efficiency.* When a boy sits for an hour with an open book, dreaming all the time of the circus, he will not have learned much at the end of the hour. His efficiency has been very low. In the same way, if a machine

is so poorly made that we do not get nearly so much out of the machine as we put into it, we say that its *efficiency is low.*

279. Be efficient. Let us call the effort that is put into a machine 100, and the work that is taken out of the machine 50. The efficiency of the machine is $\frac{50}{100}$, or 50 per cent. In some modern machines the efficiency is as high as 96 per cent, in others it is as low as 12 per cent. The higher the efficiency the better the machine. Why not apply the same reasoning to yourself? The higher your efficiency, the better your results. Work hard and play hard; that is, be efficient.

Using the formula, a pulley should require an effort of 100. But actually it requires an effort of 120. How do you explain the differences?
What is meant by saying that the efficiency of a machine is low?
What is meant by saying that your efficiency is high?

280. Screw. The last of the simple machines is the *screw.* Put your thumb nail in the groove of a wood screw, and then give the head of the screw one turn. Your finger nail has moved the distance between two grooves. By making the distance between the grooves small and the head of the screw large, a small effort can overcome a very large resistance. The friction is so great in the case of a screw that, though the formula may be applied, it is not worth while, because the results would be mis-

leading. Screws called *jackscrews* are used for lifting great weights, such as buildings. (See Figure 102.)

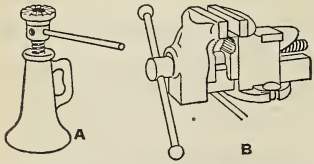


Fig. 102. A, jackscrew; B, vise

By calculation the effort required to raise a jackscrew is 100. It actually requires an effort of 400. What is one possible cause of this great difference? What is its efficiency?

281. Friction. The word "friction" has been used several times in the study of machines. We all have a general idea of its meaning. We ought, however, to know something more about it. This simple experiment may aid in giving an idea of the meaning of friction. Place a piece of rough wood on a table and try to push it along the table top. It moves with some difficulty. Try the same thing with a smooth piece of wood. It moves easily. The resistance to motion of one surface in contact with another is called friction. The rougher the wood, then, on the table, the greater the friction.

No matter how smooth a piece of metal may seem to be, when examined under the microscope the surface is seen to be made up of hills and valleys. Rub two smooth pieces of metal together (Fig. 103). The

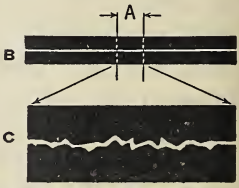


Fig. 103. B, two seemingly smooth plates; C is A magnified, showing that they are really rough

hills of one will fit into the valleys of the other. When we try to move or slide the upper piece over the lower, a resistance is felt. The smoother the metal, the less the resistance to motion or the less the friction. If a layer of oil is applied to the two pieces, the friction has been diminished by the oiling.

282. Roller and ball bearings. Place your pencil, end down, on the desk. *Push* it along. Place your pencil on its side on the desk and *roll* it along. It rolls much easier than it pushes. Advantage is taken of this in *roller bearings* (Fig. 104), such as are used in many machines, when it is necessary to reduce friction to a minimum. Ask the mechanic in a garage to show you where roller bearings are used in automobiles. Balls are sometimes used instead of rollers, as they produce less friction. Consequently, *ball bearings* are used in roller skates and various types of machinery (Fig. 105).

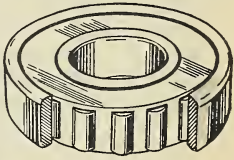


Fig. 104. A roller bearing

Fig. 105. A ball bearing

283. Use of friction. Friction is not always a disadvantage. The friction between your shoes and ice is small. Try to turn quickly on ice. You very likely will fall. If there were no friction, one could not walk, for it is the friction between the shoes and the ground that keeps one from slipping.

If there were no friction, a nail would not hold two pieces of wood together. It is the friction that makes the nail stick fast. A locomotive could not pull a train nor could a belt drive a machine without friction. Like many other things, friction is neither good nor bad. It is a useful servant in its place.

What is friction? Name several cases in which friction is useful; several in which it is of no use.
What is a roller bearing? What is its advantage?
What is a ball bearing? What is its value?
Why do we oil machines?

Experiment 48

Question: What is the advantage of arranging pulleys in various ways?

Materials: Single, double, and triple sheaved pulleys; stout flexible cord; a pound weight; a delicate spring balance reading to fractions of an ounce.

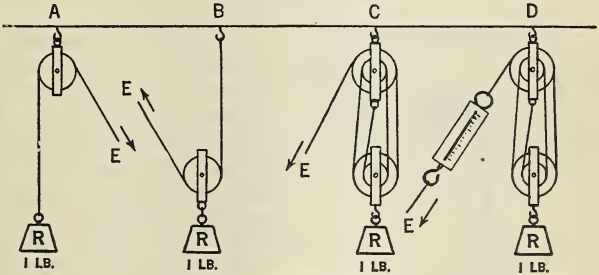
Directions: (*a*) Mount a single pulley as shown in diagram A. Pass a cord over the groove in the sheave. Tie a pound weight to one end of the cord. Pull the loose end of the cord down until you raise the weight from the table. 1. For every inch of cord that you pull in, how many inches do you raise the weight? 2. What is the only thing that this particular arrangement of a pulley does? 3. What is the advantage of this arrangement?

(*b*) Mount a single pulley as shown in diagram B. Pass a cord over the groove in the sheave. Tie a pound weight to one end of the pulley. Pull the other end upward until the weight is raised from the table. 1. For every inch of cord that you pull in how many inches do you raise the weight? 2. What is the advantage of this pulley arrangement?

(*c*) Mount two double pulleys as shown in diagram C. Pass the cord around the sheaves and hang the weight on the

pulley as shown. Pull down on the cord until you raise the weight. 1. For every inch that you pull the cord in, how many inches is the weight raised? 2. What is the advantage of this pulley arrangement?

(*d*) Using the same arrangement of pulleys as in C, attach the spring balance to the loose end of the cord as shown in diagram D. Pull the spring balance until you have lifted the weight from the table. Read the balance. 1. How many ounces of effort are required to overcome the resistance of one pound (16 ounces)? Remember the law of the lever and that



Experiment 48

this law applies generally to machines. 2. From your answer to question (*c*)1, how would you expect the spring balance to read? 3. How near does it come to this reading? 4. What might one cause of any difference be?

Diagram: Show the different arrangement of pulleys.

Conclusion: Answer the question.

Practical application: You wish to raise a barrel weighing 150 pounds. The greatest effort that you can exert is 25 pounds. Draw an arrangement of pulleys showing how you could lift the barrel.

Pulleys are often used in construction work. The next time that you pass a building that is being erected, see how many examples you can find of their use.

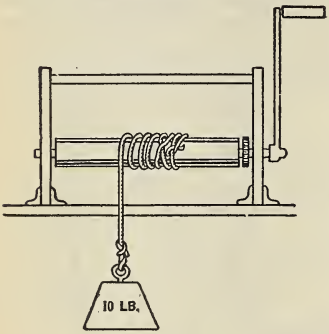
Experiment 49

Question: What is the advantage of a wheel and axle?

Materials: A clothes wringer and a ten-pound weight.

Directions: (*a*) Fasten the clothes wringer to the table and examine its construction. Separate the rollers as far as possible, and if possible remove the roller that is not driven directly by the turning handle. Oil the gears.

(*b*) Make a mark on the rubber roller and give the handle one turn. Notice that turning the handle once turns the roller once.



Experiment 49

(*c*) Tie a stout cord tightly to the roller. Wind the cord around the roller several times to prevent slipping. Tie a ten-pound weight to the loose end of the cord. Raise the weight from the table by turning the handle and thus winding the cord on to the roller. Why does the roller turn so easily in spite of the fact that you are lifting a heavy weight? (Text, Sec. **274**.)

(*d*) Measure the diameter of the roller and the diameter of the circle made by the handle as it swings around. Remember that the wheel and axle is really a modified lever having the fulcrum at the point on which the handle turns and the roller rotates. Calculate how far you must move your hand to raise the weight one inch.

(*e*) Think over the law of the lever and your answer to the problem in paragraph (*d*) above. Then answer the question: How many pounds pressure on the handle must you exert to lift the ten-pound weight?

Diagram: Show the weight being lifted.

Conclusion: Answer the question.

Practical application: The ship's capstan and the ordinary well bucket are illustrations of the use of the wheel and axle. Examine the steering wheel of your automobile and its connections to the front wheels of the car. Be ready to explain in class why a child can turn the steering wheel and so turn the front wheels while he cannot move the wheels by pushing them.

EXPERIMENT 50

Question: Of what use are skids (inclined planes)?

Materials: Two boards to represent skids. One is hinged to the other at one end, with a pulley at the opposite end, and provided with an upright and a clamp so that the angle that one board makes with the table can be changed. (See diagram.) A toy car connected to a scale pan with a strong cord; a pound weight and a set of weights.

Directions: (*a*) You of course know that to lift the pound weight vertically you must exert a pound of effort. Record this fact in the table.

(*b*) Slant the board at an angle of 60° to the table top. Place the car on the board, the cord over the pulley, and have the scale pan hanging over the edge of the table. (See diagram.) Hold the pan in your hand so that you can control its motion.

(*c*) Put a pound weight in the car. Add weights to the scale pan until it moves the car slowly upward on the board after you have given it a start. Record the necessary weight in the table.

(*d*) Change the angle of the board, making it about 45° with the table. Put weights in the scale pan as you did in (*c*) until the car moves slowly. Record the result.

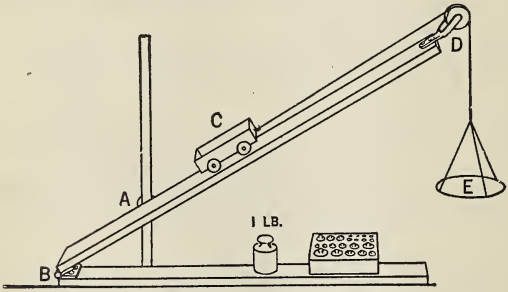
(*e*) Repeat (*d*) after you have changed the board so that it makes an angle of 30° and then 15° with the table. Record the results.

TABLE

	POUNDS
Effort required to lift a pound weight vertically.....	.....
Effort required to lift a pound weight when the skid angle is 60°.....	.....
Effort required to lift a pound weight when the skid angle is 45°.....	.....
Effort required to lift a pound weight when the skid angle is 30°.....	.....
Effort required to lift a pound weight when the skid angle is 15°.....	.....

Diagram: Show the apparatus ready for operation.

Conclusion: 1. To reach the same height, must the car travel farther when the board is at an angle of 60° or 15°? 2. From what you have learned of the law of levers, should it take a



Experiment 50

greater effort to move the car up the board when the angle is 60° or 15°? 3. Do the results you obtain (see table) confirm what the law teaches you should be true? 4. Answer the question.

Practical application: 1. If one man has to roll heavy barrels into a wagon, should he use long or short skids and why?

2. Why is it easier to walk up a gently sloping ramp than it is to walk up a flight of stairs, when both land you at the same level?

In factories and in loading trucks, skids are often used. When using skids, you roll the barrel over a greater distance than if you lifted it vertically, but the effort required to move the barrel is less. This makes it possible for one man to do work that otherwise would require the labor of several men, and this is often a convenience.

Ramps are used to make the motion of crowds easier, as in railroad stations.

Experiment 51

Question: 1. What is the relation between an inclined plane and a screw? 2. Of what use is a jackscrew?

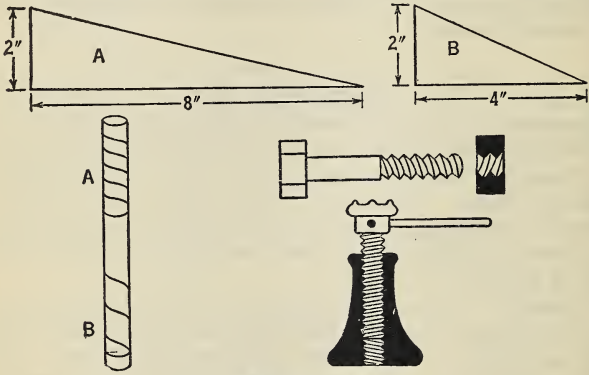
Materials: Two triangular pieces of paper which represent inclined planes. Both are 2 inches high, one is 4 and the other is 8 inches long; a wooden rod 6 inches long and $\frac{1}{2}$ inch in diameter; a large machine bolt having a coarse thread with nut; a jackscrew.

Directions: (*a*) Starting at the wide end of the paper, wrap the 8-inch-long triangular piece of paper around one end of the wooden rod. Fasten the end by pasting it down. You will see that the slanting edge of the paper which represents an inclined plane now forms a spiral around the rod. (See diagram.) To make the spiral more distinct, outline it with a blue pencil. Compare the blue outline with the machine bolt and you will see that by winding up the inclined plane you have changed it into a spiral, and that this spiral represents the thread (cut-out portion) of a screw. We call the distance between two threads (the distance between two of the blue marks) the pitch of the screw. Examine the machine-screw nut, and you will see a thread cut around the hole which goes through it.

(*b*) Wrap the 4-inch-long piece of paper around the middle of the wooden rod just as you did the 8-inch piece. Fasten

the end and outline the spiral. Compare the two spirals. You will see that the pitch (the distance between two threads) of the second screw is greater than that of the first.

(*c*) Compare the spirals you have made with the thread of the machine bolt. You will see that they are similar. If you wish, you can file out the spiral that you have marked, and thus change your inclined plane into a real screw. *A screw then is really an inclined plane wound up into a spiral.* If the rod on which you wound the paper had tapered, you would



Experiment 51

have made a spiral that would represent an ordinary tapered wood screw.

Put your finger nail into one of the threads of the machine bolt. Turn the bolt. Notice that giving the bolt one complete turn has moved your finger nail forward the distance between two threads. The coarser the thread, the farther your finger nail will move, and the harder it will be to turn the bolt.

(*d*) Both of the triangular papers that you used were two inches high. They represented inclined planes, one four and the other eight inches long. 1. Which of these two inclined

planes would require the greater effort to pull a weight up them? 2. Which then of the two screws that you made would require the greater effort to turn? 3. Why is the thread on machine screws made sometimes fine and sometimes coarse?

(*e*) Place on the head of a jackscrew as heavy a weight as you can lift. Give the screw several turns. Why does it require less effort to turn the jackscrew than it did to lift the weight on to its head?

Diagram: Show the two triangular pieces of paper, and the papers wound around the rod; the machine bolt and nut; the jackscrew.

Conclusion: Answer questions 1 and 2.

Practical application: The finer the thread, the easier it is to turn a screw and the less distance the screw will advance. Why have automobile bolts a finer thread than the ordinary machine bolt?

Jackscrews are used whenever tremendous weights have to be lifted, as in lifting a building that is to be moved. Examine the construction of the jack which is used to lift your automobile, and be ready to discuss it in class.

EXPERIMENT 52

Question: What makes automobiles skid?

Materials: A block of wood 2 x 2 x 6 inches, having two sides rough and two sides smooth; a wooden plank 8 inches by 2 feet, one side of which is smooth and the other side rough; a spring balance showing ounces; nails and hammer.

Directions: (*a*) Drive a tack into the end of your block of wood and tie to the tack a string about a foot long. Tie the other end of the string to your spring balance. Put the plank, rough side up, on the table and put on it the wood block, rough side down. This brings the two rough sides together. Put a pound weight on the block and then pull on the spring balance hard enough to move the block along the plank slowly. Read the spring balance. Try this twice

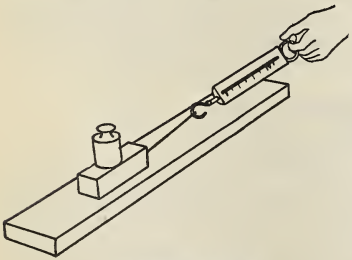
and each time take the reading of the spring balance and record it in the table.

(*b*) Turn the plank smooth side up and put the wood block on it smooth side down. Put the pound weight on the block. All things are now just as they were, *except* that the smooth surfaces are together instead of the rough surfaces. Again pull the block slowly along the plank. Try twice and record your readings in the table. Complete the table.

TABLE

	1	2	AVERAGE
Reading of the spring balance when rough surfaces are in contact.....			
Reading of the spring balance when smooth surfaces are in contact....			

We call the resistance to the motion of the block *friction.*



Experiment 52

1. Is friction greater when rough or when smooth surfaces are in contact? Why is this true?

It is the friction between the road and the rubber tires of an automobile that holds the automobile on the road. When it rains, the city streets are covered with a slime of oil and mud. When this happens, automobiles are apt to skid. 2. Explain why this is true.

Diagram: Show the block being drawn along.

Conclusion: Answer the question.

Practical application: What holds a nail in wood? What would happen to wooden boxes held together with nails if friction should cease to exist?

CHAPTER THIRTY-FOUR

AIR-PRESSURE PUMPS

284. The check valve. Water may flow freely through a pipe in one direction. To prevent it from flowing in the opposite direction, a *check valve* is used. A simple check valve is shown in Figure 106.

The valve is a piece of leather, held in place by a nail passing through it. A small shelf having a hole in the middle is placed in the pipe. The leather disk fits over this hole and overlaps it. Water can freely pass *up* through the pipe, for the leather disk will lift, allowing the water to flow around it. Water cannot pass *down* the pipe, for as soon as the water starts to move down, the leather is pressed tightly against the shelf and thus closes the passage. The more pressure we apply *downward*, the tighter the leather is pushed against the shelf and the more difficult it is for the water to pass through.

Fig. 106. Which way will this check valve allow water to pass through the pipe?

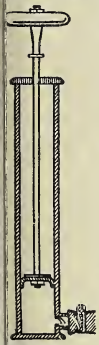


Fig. 107. A bicycle pump

285. The bicycle pump. Such check valves are in common use. One use is in the bicycle pump. The *piston* of the pump

has a cup-shaped leather washer (Fig. 107). The piston may be drawn up easily, for the leather washer is then loose in the cylinder and air can leak through it. When the piston is forced down, the leather washer flattens, and air cannot get by it. Therefore, when the piston is pushed down, the air in front of it is compressed and forced into the tire.

What is the object of a check valve?
How is a simple check valve made?
Waste water from a house passes through a waste pipe into the sewer. Show by diagram how this waste water may be prevented from flowing back into the house pipes.
Explain the mechanism of a bicycle pump.

286. One atmosphere pressure. You will remember that when we studied the barometer (Secs. 225, 226), we found that the air presses down on the surface of the earth with a force of 15 pounds a square inch. This is often called a pressure of *one atmosphere.* This is just what we should expect, for, since air is matter, it has weight and must press down on whatever supports it.

287. A surprising fact. Can you turn a glass of water upside down and not let the water run out? Let us tell you how to do it. You will learn something about air pressure by doing this trick.

Fill a glass with water, put a wet piece of paper over the top of the glass, put your hand on the paper, and turn the glass upside down. Take away

your hand and the paper will be held on the glass by the air pressure. No water will escape (Fig. 108).

To make this experiment a success, requires some care. The glass must be full of water so that, when you place the paper cover over the glass, there will be no air between the paper and the water. The paper used should be hard, and must fit closely, leaving no air holes. A good writing paper is satisfactory. It makes the experiment more certain if the paper is cut into a circle a little larger than the top of the tumbler. Wet it before use, so that it will press tightly to the glass. Try this experiment at home.

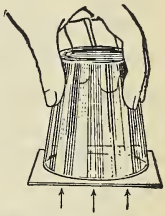


Fig. 108. Air pressure keeps the water in the glass

What is meant by a pressure of one atmosphere?
What is the air pressure on one square foot of the earth's surface?
In the experiment just given, why does the water not run out of the glass?

288. Air presses in all directions. Because air is a gas, at any point this air pressure is exerted equally in all directions. Hold out your hand. If air is pressing down on it with a force of 15 pounds a square inch, you might expect that this pressure would make it impossible for you to hold out your hand. But you may not realize that there is any pressure on it. This is because the *air under your hand is pressing upward with the same force with which the air above your hand is pressing downward.*

At first it seems impossible that air pressure can act at any one point in all directions, up, down, and sidewise. But this must be true, for if it were not so, we would feel the unequal air pressure on our bodies.

Hold a small-mouthed bottle to your mouth; draw out some of the air. Put your tongue over the mouth of the bottle and it will be drawn in. The bottle will hang suspended, because the outside air pressure is no longer balanced by the air pressure in the bottle.

289. Pressure on our bodies. Another fact that makes it hard to believe that air pressure exists is that our bodies are not crushed by it. You might think that, since the surface of your body is at least 1,500 square inches, if a pressure of 15 pounds a square inch existed on it, or 22,500 pounds over the whole body, you would be crushed. But you must think about the air pressure inside your body. Inside your lungs, for example, there is an outward pressure of 15 pounds a square inch, due to the air which you have breathed in; this outward pressure just balances or equals the inward pressure. Anything that suddenly changes the outside air pressure will make you very uncomfortable, for then the two pressures will not balance, and you will suffer.

Why do we believe that air pressure is equal at any point in every direction?

A man may hold out his hand, but there is a downward air pressure on his hand of more than 500 pounds. How is this possible?
Why does the air pressure not crush our bodies?
When going up Pikes Peak on the cog railroad, persons often complain that their ears feel as if they would burst, and they suffer a great deal of discomfort. Why?

290. Air pressure helps us to breathe. Breathing itself is due to air pressure. We talk about drawing air into the lungs, but this we cannot do. What happens is that we raise our ribs and draw down the large muscle, called the *diaphragm*, at the lower end of the lungs. This makes the box, called the *chest cavity*, larger and lessens the air pressure inside of it. The outside air pressure then forces air into the lungs.

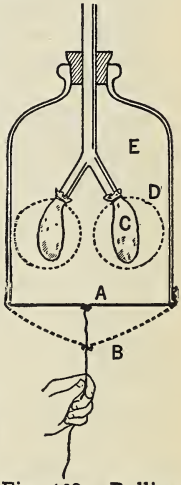


Fig. 109. Pulling the rubber A to the position B diminishes the air pressure in E causing the balloon to expand to D. This illustrates the reason why our lungs expand when we lift our ribs

A simple piece of apparatus shown in Figure 109 will make this plain. When we pull down on the rubber A that represents the diaphragm, we increase the space inside the bell jar and thus decrease the air pressure. The air pressure outside the bell jar is then greater than the pressure inside, and air is forced into the two rubber balloons. These balloons swell just as our lungs do.

Pushing the rubber diaphragm in, increases the air pressure inside the bell jar. Air pressure then pushes the air out of the balloons and they collapse, just as do our lungs under the same conditions.

How is our breathing dependent on air pressure?
Men who can expand their chests a great deal can also breathe very deeply. Why?
Put a medicine dropper or ink filler into a glass of water. Squeeze the bulb and air bubbles out into the water. Let go the bulb and water goes into the tube of the dropper. Why?

291. Lift pump. Many farmhouses are dependent on wells for their water supply. Some of you, probably, have had the job of going to the well to draw a bucket of water and then carrying it into the house. This is hard, slow work. To avoid it, a lift pump is used.

To explain the principle of a lift pump, we must again talk about air pressure. Imagine an iron pipe leading from the surface of the earth to the water in the well (Fig. 110). In this pipe place a solid piston P, having a long rod attached to it, so that it can be moved up and down. Push the piston down until all of the air has been pushed out of the pipe, and the piston rests on the water in the well. It will then be in the position shown in Figure 110, Diagram A. Lift the piston by the rod. There will be no air pressure on the water inside the pipe, for this air pressure will act on the top of the piston. When you lift the piston, you overcome

that. The water in the well, though, will be pressed by a force of one atmosphere. Water will be pushed up the tube by this pressure. If the piston has an area of one square inch, it will take a force of 15 pounds to lift it.

After the piston has been lifted, start to push it down. The water in the pipe will then be forced back into the well. To prevent this, a check valve V that opens only when the piston rises, is placed in the pipe. Now, we cannot push the piston down, for there is no place for the water to go. Let us place a second check valve V′ in the piston itself, that opens only when the piston is pushed down. Now we can push the piston down, because this check valve (V′) will open and the water in the pipe will flow to the top side of the piston. The next time we lift the piston, the water will flow out of the top of the pipe. But we may make it more convenient if we use a pump arranged as shown in Figure 110, Diagram B. This type of pump is in common use.

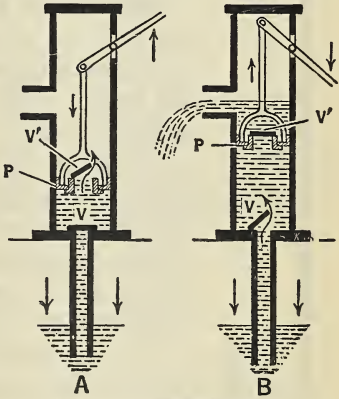


Fig. 110. The lift pump

A pressure of one atmosphere will lift water 34 feet. That is, a column of water 34 feet high and 1 inch square in cross section weighs 15 pounds (Fig. 111). If the lift pump were perfect, it would pump water to a height of 34 feet. The pump, however, usually leaks, so 25 feet is about the maximum lift.

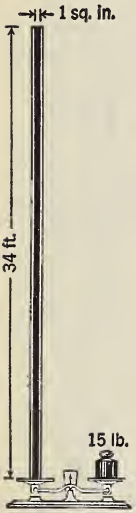


Fig. 111. A column of water 34 feet high and 1 inch sq. weighs 15 pounds

292. Force pump. The force pump depends on air pressure, but its construction is somewhat different from the lift pump. The piston P (see Fig. 112) is made solid. As the piston rises, the same effect is produced as in the lift pump. Air pressure on the water in the well forces water into the pump cylinder. When the piston goes down, however, this water is forced through the check valve V′ into the pipe C and gushes out of the nozzle N. We can force the piston down with a great pressure, and thus push the water out of the nozzle with much force. Each stroke of the pump causes a gush of water.

Like a lift pump, a force pump cannot, at the most, lift water more than 34 feet. Since, however, the force with which the water gushes out of the nozzle depends only on the pressure with which the piston is forced down, the pump can throw water to a con-

siderable height. Fire engines often use force pumps.

Explain, with the aid of a diagram, the operation of a lift pump.
With the aid of a diagram, explain the operation of a force pump.

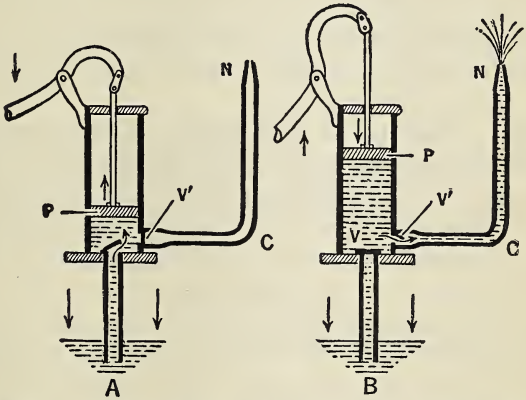


Fig. 112. The force pump (see Section 292 for explanation)

Why will a lift pump not raise water to a height of 60 feet?
Is a force pump ever used to pump gasoline? Explain your answer.

293. Gravitation. We know that if a ball be dropped, it falls to the earth. The earth seems to attract the ball. This force of attraction is called *gravitation*. But this is only half the story. Not only does the earth pull the ball *downward*, but the

ball pulls the earth toward it. *Gravitation is a mutual action.* If one jumps from a chair to the earth, one can truthfully boast that he is strong enough to move the earth. He need not say how far he moves it, for the distance is too small to measure.

When you study physics, you will learn that every particle of matter in the universe attracts every other particle, and that it is this attraction that keeps the earth swinging around the sun, and holds the stars in their courses.

294. Measure of gravitation. The nearer two bodies are to each other, the stronger is the pull of gravity. The larger the bodies, the stronger the pull. The sun is so much larger than the earth that gravitation on the sun is much stronger than on the earth. If one could be taken to the sun, he would weigh perhaps a ton. The moon is so much smaller than the earth that its pull of gravity is much less than the earth's pull. If one could be taken to the moon, one's weight would be much less than it is on earth, for *weight is the measure of the attraction of gravitation.* A weight of one pound on the earth is a weight of 28 pounds on the sun, and $2\frac{1}{3}$ ounces on the moon.

295. The planet Neptune. One wonderful example of the possibilities of science was the discovery of the planet Neptune. It had been noticed by astronomers that the planets did not always appear in the heavens in the places that calculation showed

that they should be. Leverrier, a mathematician, thought that this might be because there was some unknown planet that, by its gravitation pull, was sending the other planets out of their places. He made the necessary calculations, and told the astronomers that if, at a certain time, they would look at a certain place in the sky, they would see a new planet. The astronomers turned their telescopes on this spot, and, sure enough, the new planet Neptune was there.

What causes the weight of bodies?
If you weigh 100 pounds on the earth, what would you weigh on the sun? Why? on the moon? Why?
What do we mean by saying that gravitation is a mutual action between bodies?

Experiment 53

Question: How can I make a check valve, and of what value are check valves?

Materials: Check valve, as described below; water under pressure.

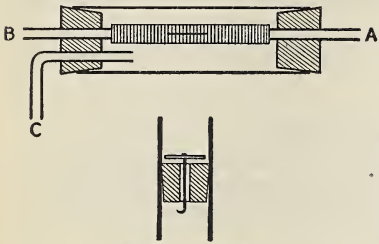
Directions: (*a*) In a three-inch-long piece of thin, flexible rubber tubing cut a slit one-half inch long. Place a short piece of glass tubing in each end of the rubber tubing. Slip a rubber stopper over each piece of glass tubing, and fit these into a longer piece of larger glass tubing as shown in the diagram. One rubber stopper carries the two pieces of glass tubing B and C.

(*b*) Attach end A of the glass tubing to the water faucet, and turn on the water. Water will come out of the ends B and C, for the sides of the slit in the rubber will be forced apart, and water will go through.

(*c*) Reverse the ends and attach tube C to the water faucet. Turn on the water and you will find that no water will come out of A or B, for the water pressure will force the sides of the slit together and water cannot pass through.

(*d*) Empty the apparatus and blow througn end A. Air will go through without any difficulty. Blow through tube C and you will find it impossible to force air through.

(*e*) Exercise your ingenuity and see whether you can make for yourself some other form of check valve. Try, for instance, the result of forcing a rubber cork with a hole through it all the way into a glass tube and then putting a small disk of sheet rubber over the hole. (See diagram.) Wet the rubber and then try blowing through the tube, first from one end and then from the other. You can easily make other forms of check valves.



Experiment 53

Diagram: Show two forms of a check valve.

Conclusion: Answer the question.

Practical application: Check valves are used in pumps of all kinds, and in pipes carrying liquids when we wish to prevent a back flow of the liquid. One of the authors of this book once lived in a house that stood on low ground in a section of the city of Brooklyn. When violent storms came, the storm sewers could not carry the water away as fast as it fell, and water would back up into the cellar through the plumbing fixtures. The placing of a check valve in the line prevented this and kept the cellar dry.

CHAPTER THIRTY-FIVE

WAVES

296. Air disturbances. In the spring of 1924 a heavy explosion occurred at the Nixon Nitrate Works at Black Tom, New Jersey. New York City is thirty miles from the scene of this catastrophe, yet streets in lower New York were covered with broken glass from the windows in the skyscrapers. The Whitehall Building, for example, had many windows broken, some of them of heavy plate glass that could withstand a heavy shock.

When the windows in our houses shake and rattle, someone often says, "That must have been a heavy blast." Is it not curious that a blast miles away can break a window glass? It cannot be that the air is blown so far, for then we should feel a terrific wind, and we know that such a wind does not occur, yet the damage must be due to a disturbance of some kind in the air.

297. Water waves. If you will fill a basin with water, wait until the surface is smooth, and then drop a small stone into the water, you will cause *waves* (Fig. 113). Everyone has *seen* such waves, but perhaps not everyone has *thought* about them. Look at the waves you have produced. They spread

out in rings with the stone as the center. As these rings increase in number, the height of the wave grows less, but *the distance between the rings remains the same.* When the circle of waves strikes the side of the basin, you will notice that the waves are reflected, or turned back, and that these reflected waves *pass through the original waves without disturbing them* (Fig. 114). Waves going in different directions can pass through each other without undergoing any change. This is often seen in waves in a bay, where projecting points of land cause the reflection of waves.

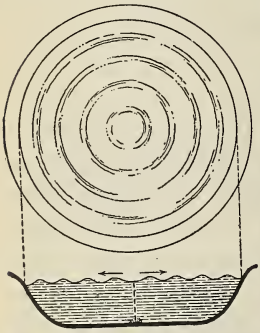


Fig. 113. Water waves produced by dropping pebble into basin of water

298. Air waves. When the wave strikes the side of your basin, you will notice that the direction of the wave is changed. Reflection, then, may change the direction of motion of a wave *without altering the wave in any other way.* You will now understand what the disturbance in the air was that broke the glass. It was an *air wave.* The more violent the explosion, the more energy is used in pushing the air, and the more violent the wave in the air.

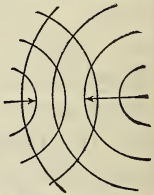


Fig. 114. Waves can pass through each other without interference

299. The wave moves onward. Ask one of your classmates to tell you what will happen if a water wave strikes a drifting boat. The answer will probably be, "Why, the wave will carry the boat along with it." Before you ask the question, you had better try an experiment, so that you can reply with confidence, "You are wrong. The boat will only rise and fall. It will not move onward with the wave."

Let the water in the basin come to rest. This will take some time, for there must be no currents in the water, or your experiment will fail. Drop a match on the water to represent the drifting boat. Now drop a stone to start a set of water waves. You will see that the match rises and falls, but does not move forward or backward. In water waves, then, *the wave moves onward*, but the matter of which the wave is formed *does not move onward, but moves only up and down.*

A field of tall grass shows this wave motion beautifully. Waves started by the wind pass from end to end of the field; the grass stalks only sway back and forth. The wave moves onward; the grass does not.

300. Parts of a wave. To make it easy to talk about waves, there are a few new words that we must learn. We speak of the top of the wave as the *crest* and the bottom of the wave as the *trough* (Fig. 115). The distance from the top of one wave to the top of the next we call the *wave length*. The

mean height of the wave we call the *amplitude*. There are many ways to represent a wave on paper; the simplest way is to draw a curved line similar to that in Figure 115.

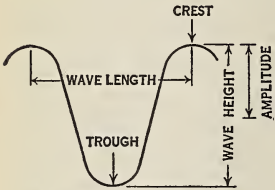
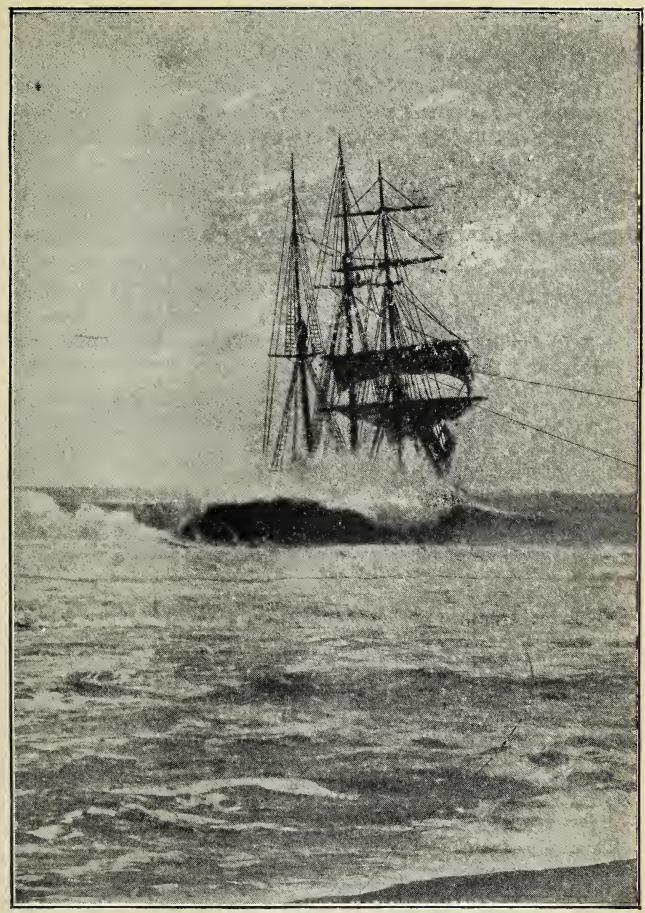


Fig. 115. Parts of a wave

301. Surf: obstructed waves. In shallow water, waves do not follow the rules we have given, because the bottom of the wave drags on the sand and consequently moves more slowly than the top. This causes the top of the wave to fall over, and *surf* is formed (Fig. 116). In midocean, where the water is deep, surf does not occur. Whitecaps are formed by strong winds which blow off the tops of waves, leaving a white foam on the crest of each wave. In surf there is an actual onward motion of some of the water.

302. Size of waves. We have spent some time in the discussion of waves, because you will find it necessary to understand them in your study of sound, light, heat, and electricity. In the ocean there are waves of a length of 1,000 feet and a height of 40 feet. In light there are waves 0.00015 inch long, but no matter what the length of the wave may be, all you have learned about them will be true.

How can a distant blast break a window glass? What is a water wave? How do you know that the water itself does not move onward?



Courtesy Merritt-Chapman & Scott Corp.

Fig. 116. The huge wave in the middle of the picture is breaking into surf in the center

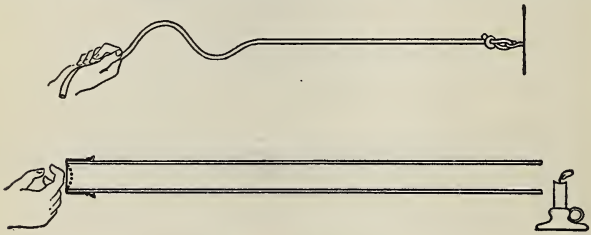
Give a case of the reflection of water waves.
Explain what is meant by the crest, the trough, the amplitude, and the wave length of a wave.
What is the longest wave and the shortest wave that you know?

Experiment 54

Question: How can I make and reflect a wave?

Materials: Pan of water; ten-foot-long piece of rubber tubing; small stone; long glass tubing; rubber dam; candle.

Directions: (*a*) Fill a large pan with water and allow it to stand until the water has come to rest. Drop a small stone



Experiment 54

into the center of the water. Notice that the ripples (tiny waves) produced spread out until they reach the sides of the pan and then are reflected and go toward the center again. What name do we give to the top of the wave? the bottom of the wave? the distance from the top of one wave to the top of the next? (Sec. **300**.)

(*b*) As the waves in the pan spread out, their height became less. Did their wave length vary?

(*c*) Tie one end of the rubber tube to a hook on the wall or to some heavy piece of furniture. Hold the other end in your hand and pull the tube straight. Strike the tube a sharp blow near your hand. Notice that you produce a wave in the tube, that this wave moves along the tube to the wall, is there

reflected, goes back to your hand, is again reflected, and gradually dies out. Are waves formed only in liquids, such as water?

(*d*) Over one end of a glass tube about three feet long and one and a half or two inches in diameter tie a piece of thin rubber sheeting (rubber dam) such as dentists use. Hold the tube horizontally in a clamp and put a lighted candle close to the open end. Tap the sheet rubber sharply with your finger. Notice that the candle flame is blown to one side as if a wind had struck it, yet the tube is closed at the end by the rubber so that no wind can blow through it. 1. What did your blow cause in the air in the tube? 2. Are waves formed only in liquids and solids?

Diagram: Show waves in water and a wave passing through the long glass tube and blowing the candle flame.

Conclusion: 1. Name the parts of a wave. 2. Give a case of the reflection of a wave. 3. In what materials can a wave be produced?

Practical application: Sound, light, and electricity are all caused by waves of varying kinds. Echoes are caused by the reflection of sound waves.

NOTE: The energy possessed by some of the huge ocean waves is almost unbelievable. Large ocean liners have had the bridge of the ship completely carried away by one of these waves striking it. A hurricane in the South Seas once caused such enormous waves that a vessel at anchor in the harbor was carried bodily inland for a distance of a quarter of a mile and dropped on the beach. When the wave receded, the ship was left on dry land, and there it remained, for it would have cost more to drag it back to the water than to build a new ship. Sound waves do not possess so much energy as the ocean waves, yet even a strong sound wave in the air can break a window.

CHAPTER THIRTY-SIX

SOUND

303. What is sound? Before studying sound, we should know something about its cause. Stretch a rubber band over the thumb and finger and pluck or pull it. You will *hear* a sound and *see* that the string is vibrating, or moving to and fro. Stretch the rubber band more tightly. The sound is now different, but the band is still vibrating. If your eyes are good, you can see that it is vibrating in a different way. It vibrates more rapidly than it did at first (Fig. 117).

Fig. 117. A vibrating rubber band

From your study of waves, it seems reasonable to believe that the rubber band in vibrating strikes the particles of air that are in contact with it. This causes a *wave* in the air and this wave, striking the ear, causes the sensation we know as sound. Sound, then, is *wave motion.*

304. Transmission of sound. The next time that you go in swimming, ask a comrade to knock two stones together under water very gently, while your ear is under water. You will hear the sound

more loudly than when the stones are knocked together in the air. Air, then, is not the only material that can transmit or carry sound. If the rails of a trolley system are welded together, they transmit sound for long distances. Place your ear on a trolley rail and you will hear the hum of the approaching car long before you hear it through the air.

305. Sound waves. Sound, then, is caused by a vibration or *a wave in some material substance* (Fig. 118). Air, water, iron, and, in fact, all materials,

Fig. 118. The cause of sound

transmit sound. The longest sound wave in air that we can hear is about 64 feet and the shortest about .03 feet long. There is reason to believe that animals can hear much shorter waves than this.

Give proof that sound is caused by a vibration.
Name cases of the transmission of sound by air, iron, water.
What are the longest and the shortest sound waves that can be heard?
Give a proof that sound waves possess energy.

306. How sounds differ: loudness. Sounds differ from each other in *loudness*, in *pitch*, and in *quality*. Once more stretch a rubber band and pluck it gently. You will hear a faint sound. Pluck it

strongly and you will hear a much louder sound. You have given the band more energy, causing it to strike the air particles much harder. This in turn gives a sound wave of larger amplitude and a louder sound. The more energy you give to the vibrating band, the more it can give out, and the louder will be the sound. Try this same experiment with a bell or a violin. The same thing will happen.

307. Pitch. By *pitch* we mean the highness or the lowness of the sound. A bass sings notes of *low pitch,* while a soprano sings notes of *high pitch.* The easiest way to study pitch is by the use of tuning forks.

308. Counting sound waves. By using wax, attach a bristle to the end of a tuning fork. Smoke a piece of glass by holding it over a candle flame. Set the tuning fork in vibration and draw the bristle over the smoked glass (Fig. 119). As the vibrating bristle moves to and fro, it will trace a line on the smoked glass, each curve of which represents one vibration or wave. Add a pendulum that will beat 0.1 second, and attach a bristle to the bob. Swing this across the smoked glass at the same time that

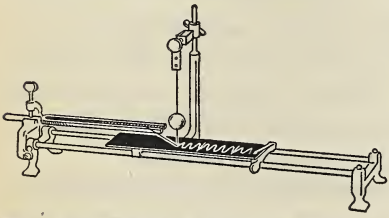


Fig. 119. Tracing a sound wave on a piece of smoked glass

the tuning fork is making its record on the glass. You will be able to find out how many vibrations the tuning fork makes in 0.1 second. This will be the number of waves between the two pendulum marks on the glass, and these may be counted. Figure 120 shows such a record on smoked glass, from which you can find out how many waves the tuning fork made in the 0.1 second.

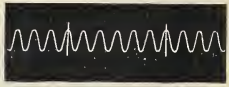


Fig. 120. A sound wave record

309. Pitch and vibration number. By studying such records, it has been found that the larger the number of vibrations, the higher the pitch. Middle C on the piano is caused by 261 vibrations a second. Tuning forks are generally adjusted so that middle C makes 256 vibrations. The reason for this difference is that doubling or halving the number of vibrations raises or lowers the pitch one octave, and 256 can be more easily divided in this way than 261. A tuning fork then of $\frac{256}{2}$, or 128 vibrations, gives the octave lower than middle C, while $\frac{128}{2}$, or 64 vibrations, gives the next lower octave.

Pulling strings tightly increases their rate of vibration. It is in this way that all stringed instruments are tuned. Heavy wires vibrate more slowly than light ones. The piano, therefore, uses heavy wires for the low notes, and the fine wire strings of the mandolin produce high notes.

Pitch, then, depends on *the rate of vibration.* The *higher* the rate of vibration, the *higher* the note produced.

What is meant by pitch?
Upon what does pitch depend?
Middle C of a piano is flat; that is, too low in pitch. How can this be remedied, and why would your method work?
A violin tone is sharp; that is, too high in pitch. How can you remedy the trouble?
How many vibrations a second will give the third octave above middle C, using the tuning-fork scale?

310. Sound quality. Perhaps you have heard two sisters speak, without seeing them. Their

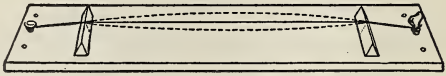


Fig. 121. A vibrating wire causes sound

voices are alike in loudness and pitch, yet you have no difficulty in distinguishing between them. Or you listen to an orchestra. Piano, violin, trombone, all are easily recognized because the sounds differ in *quality.*

311. Cause of quality. Hold down the piano key that strikes the octave above middle C, but not enough to cause the note to sound. Thump the middle C key several times. Let the middle C key come up. Listen while still holding the octave key down. You will hear distinctly the note of the octave above middle C. When you strike middle C,

then, you really cause not *one* but at least *two* notes to sound.

To explain the cause of this, we shall need a stretched string with which we can experiment. Fasten a steel wire to a board as shown in Figure 121. Pluck, or bow, the wire in the middle and set it in vibration. You will hear a musical note, due to the string vibrating as a whole.

Touch the wire at its middle point, using your finger tip, and again bow the wire at a point one quarter of the distance from the end. Now place a paper stirrup over the middle point of the wire. The stirrup will move around slightly but will not be thrown off

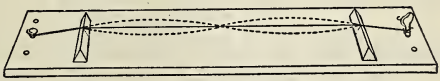
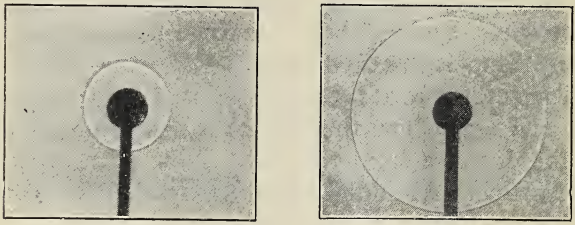


Fig. 122. A wire vibrating in halves

as you would expect it to be. This is because the wire is now vibrating in halves (Fig. 122).

312. Fundamental and overtones. A stretched string, then, will vibrate not only as a whole but in parts, and each part of the string will give out its own note while the string as a whole is giving out or sounding the main note. We call the main note produced by any musical instrument the *fundamental.* The other notes produced at the same time we call the *overtones.* It is these overtones that determine the quality of the sound. A piano and a violin give different overtones and, therefore, have a different quality.

313. Overtones cause quality. In a piano, the point where the hammer strikes the string is fixed, and hence the same overtones are always present in each fundamental note. In a violin, the point where the string is bowed can be changed, and so the over-



A B

Photos by Prof. A. L. Foley, Indiana University

Fig. 123. A, photograph of a spherical sound wave taken 0.0001 seconds after the spark that produced the wave; B, sound wave taken 0.00015 second after spark

tones present can be changed. In this way the quality of the violin notes produced can be varied.

A jew's-harp produces only one fundamental note, yet a tune can be played on it. This is because the vibrating tongue of the harp gives many strong overtones. By varying the shape of the mouth, the player makes you hear one or the other of these overtones and at the same time subdues the fundamental note.

314. Quality of tone. Quality of tone, then, depends on the fact that it is possible to produce many different waves at the same time from one

string. It is the combination of these waves that we hear that gives the quality of the sound and enables us to distinguish between different instruments and voices (Fig. 124).

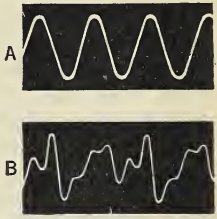


Fig. 124. Cause of sound quality. A, record of wave produced by tuning fork; B, record of wave produced by human voice.

What is meant by the quality of a sound?
To what is sound quality due?
What makes it possible for you to distinguish between a violin and a piano note of the same pitch and loudness?
What is meant by the fundamental note and what by the overtones of a string?
How is it possible to vary the quality of a violin note?
Why cannot the quality of a piano note be changed in the same way?

EXPERIMENT 55

Question: How is a piano tuned?

Materials: Strings mounted on a sounding board. One end of the board carries pulleys so that weights may be hung on the ends of the strings to stretch them (see diagram); set of weights; wires of different sizes and materials.

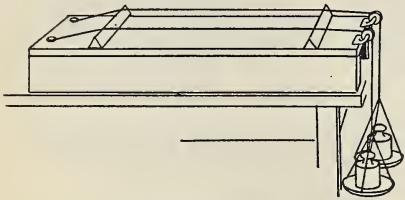
Directions: (*a*) Put two strings of the same size but of different material on the board. One may be steel and the other catgut or brass. Stretch both strings equally tight by hanging a five-pound weight in each pan. Pluck each string and notice that the pitch of the sound produced is not the same for the steel as it is for the other. Other conditions being the same, how does the material used affect the pitch of a string?

(*b*) Take off the catgut string and use instead another steel wire much heavier than the first steel wire. Pluck both strings,

after you have stretched them equally tight by putting the same weight in each scalepan. 1. Which gives the higher note? 2. How does the size of a wire affect the pitch of the note it gives out?

(*c*) Take off the heavy wire and put on a steel wire just like the first one. You now have two wires on the board just alike. Hang the same weight in both pans and pluck the wires. They will, of course, give the same note. Double the weight in one scalepan and again pluck the wires. How does increasing the tension (pull) on a wire change the pitch of the note it gives out?

(*d*) Adjust the tension on the two wires so that it is the same. Pluck both wires to be sure that both give notes of the same pitch. Put a movable bridge under the middle point of one wire so as to make the vibrating part only one-half as long as the other. Pluck both wires and compare the notes given out. How does making a wire one-half as long affect the pitch of the note it gives out?



Experiment 55

Diagram: Show the wires stretched.

Conclusion: 1. Why are the low notes of a piano given by long, heavy wires? 2. Why are the high notes given by short, thin wires? 3. How is a piano tuned by the use of the pegs at the ends of the wires?

Practical application: Different instruments use wires of different materials to vary the pitch (and quality) of the notes. Violins are tuned, as are pianos, by varying the tension on the strings. What other instruments are tuned in this way?

CHAPTER THIRTY-SEVEN

APPLICATIONS OF SOUND

315. Velocity of sound. Watch a carpenter working on a building some distance away. He strikes a nail, and some time after you have *seen* the blow, you *hear* the sound. In the same way the flash of a cannon is seen before the sound is heard. Evidently it takes sound waves some time to travel through air.

We can learn how fast sound travels in a simple way, but the results will not be very accurate. It may be that you live in a town where a locomotive-wheel rim suspended from a rod is used as a fire alarm. If so, measure 1,100 feet in a straight line from the rim. Place a boy with a hammer in his hand close to the rim. You yourself stand at the end of the measured distance.

Signal the boy to strike the rim with the hammer. The instant you *see* him strike the tire, begin to count seconds. The instant you *hear* the sound, stop counting. If you have a stop watch, that is, a watch so arranged that you can use it to count $\frac{1}{5}$ second, use that. If you have not a stop watch, use a pendulum that beats quarter seconds. You can easily construct such a pendulum if necessary.

316. Velocity of light. Light travels with the enormous speed of 186,000 miles a second, so that we need pay no attention to the time it takes light to travel from the boy to you. The measured distance was 1,100 feet and you heard the sound one second after you saw the blow. It must have taken sound one second to travel 1,100 feet. The velocity or speed of sound, then, is 1,100 feet a second. This velocity varies slightly with the temperature and other causes, but for our purposes 1,100 feet a second is close enough.

A knowledge of the velocity of sound is often useful. Suppose, during a thunderstorm, that you see lightning. Six seconds later you hear the thunder. In six seconds sound travels 6,600 feet. The lightning, therefore, is more than a mile away, and there is no probability of its being dangerous to you.

317. Echoes. When we studied about water waves, we learned that *waves can be reflected.* This reflection of waves in air is the cause of *echoes.* Stand some distance away from the side of a large barn, and shout. You will hear your shout, and shortly afterward you will hear the repeated shout, or the echo. Since you know the velocity of sound, you will learn how far away the reflecting surface is. If you heard the sound two seconds after you had shouted, the sound must have traveled 2,200 feet. As it had to go to the barn and back again, the barn must have been $\frac{2200}{2}$, or 1,100 feet distant.

318. Depth finding. Scientists are interested in knowing the shape and depth of the ocean bottom, but to find this has been a slow and expensive process. The usual method has been to drop a weight hung from the end of a steel wire. The time needed to reel and unreel the wire has made it impossible to take many soundings in a day's time. Now we start a sound wave traveling toward the ocean bottom, and listen for the echo. Since we know the velocity of sound in sea water, and the time that it takes the sound wave to travel to the bottom and back again, we can easily determine the depth of the ocean at that point.

Why do we not hear the sound of a distant cannon at the same time that we see the flash?
How do you determine the velocity of sound?
You see a flash of lightning, and ten seconds later you hear the thunder. How far away is the storm?
What is the cause of an echo?
How is the depth of the ocean determined?

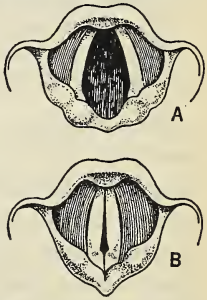


Fig. 125. The vocal cords. A, quiet inspiration; B, singing a high note

319. How we talk. If you will press your finger on your throat, you will feel the *windpipe*, or *trachea*, a tube that leads from the mouth to the lungs. At the upper end of this windpipe is a small box known as the Adam's apple or *larynx*. Across the top of this

are stretched two thin strips of cartilage. Cartilage is a tough, elastic tissue. Air from the lungs passes over these two strips, called *vocal cords*, and when they are tightened and set in vibration, sound waves are produced (Fig. 125).

320. Pitch of voice. The vocal cords are usually shorter and lighter in women than in men. Women's voices are therefore usually higher in pitch than men's voices. We vary the pitch of the sound that we produce by altering the pull on the cords, using for this the muscles that are attached to them. When we have a cold, mucus is deposited on the cords and they become thicker and rough. It is for this reason that our voice is of lower pitch when we suffer from a cold.

How do we produce sounds?
Where are the trachea, the larynx, and the vocal cords?
What is the use of each of them in producing sound?
How do we vary the pitch of our voices?
Why do our voices change when we have a cold?

321. The ear. The ear, as it is familiarly known, has little to do with hearing. The outer ear is so shaped that it reflects sound waves into the true ear, but its main purpose is to serve as a protection to the tube that leads from this external outer ear to the hearing device. From this external ear a short tube leads into the head. The inner end of this tube is closed by a thin, elastic membrance that is called the *eardrum*.

322. Auditory nerve. Behind the eardrum are three small bones, the hammer, the anvil, and the stirrup, so named from their shapes. The last of these, the stirrup, is attached to the drum of the inner ear. This inner ear is shaped like the coils of a snail's shell, and is filled with a liquid in which are stretched more than 3,000 sound nerve ends. These unite to form the sound or *auditory nerve* that goes to the brain.

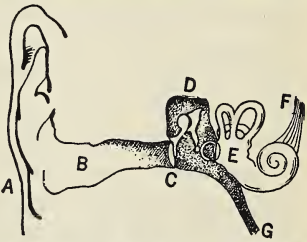


Fig. 126. The structure of the ear. A, external ear; B, ear canal; C, eardrum; D, inner ear containing the three small bones which transmit the sound waves to the cochlea E; F, nerves of hearing connected with the brain; G, tube connecting inner ear with throat

The middle ear, containing the chain of three tiny bones, is filled with air, and is connected by a tube, called the *Eustachian tube*, to the back of the mouth (Fig. 126).

323. How we hear. When a sound wave strikes the eardrum, it sets the eardrum in vibration. This vibration is carried by the chain of small bones to the internal ear (cochlea), and there it affects one or more of the nerve fibers. This nerve telegraphs the sound to the brain and we hear. It is by educating our ear that we know what each sound means. Any disease that injures the auditory nerve affects our hearing, for it is not until this nerve has sent a message to the brain that we hear.

324. Care of the ear. The best care that we can take of our ears is to let them alone. The eardrum is so near the surface of the head that poking hard objects into the ear to clean it is likely to break the drum. An old and true saying is that nothing smaller than your elbow should ever be put into the ear. Washing the ear and using a soft cloth to remove the wax that forms at the outer end of the ear tube, are all that are allowable.

Should an insect get into the ear, a very little lukewarm olive oil dropped into the ear will cause the insect to float to the top of the tube. It then may be removed with absorbent cotton without injury to the eardrum. The cotton also serves to remove the oil. In the case of an earache, the application of dry, mild heat, using a hot cloth or a hot-water bag, will sometimes afford relief.

Diseases of the ear, besides being very painful, often cause deafness. *If you have any trouble with your ears, go to a physician at once. Delay may cost you your hearing.*

Show by a diagram the structure of the ear.
How does a sound vibration reach the inner ear?
Explain how we hear sounds.
Why is it important to let your ears alone?
How may deafness be caused?

325. Principle of the phonograph. Vibrating bodies produce sound. The reverse of this statement is also true—sound produces vibrating bodies. You

have learned both these facts in your study of sound. Now we shall see how they make the phonograph possible.

Fasten a short, sharp-pointed needle to the center of a thin, flexible mica disk. Put a glass plate covered with a layer of wax below the point of the needle (Fig. 127). Mount the plate so that it can be drawn along under the needle point, just touching it. By doing so, you will scratch a fine, uniform groove in the wax.

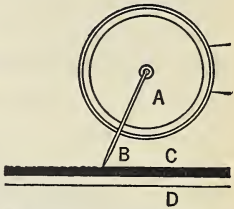


Fig. 127. Making a simple phonograph record. A, diaphragm; B, needle; C, wax; D, glass

Placing your mouth close to the mica disk, say, "ah" loudly. This will set the disk in vibration and the attached needle will therefore move up and down. At the same time draw the waxed plate under the point of the needle.

Using a magnifying glass, examine the groove that the point has cut in the wax. You will see that the groove is no longer uniform. It is now made up of a series of hills and valleys, caused by the to-and-fro motion of the sharp point. You have made a crude phonograph record.

If you will draw the plate along once more under the needle point, keeping the point in the groove you have made, you will see that these hills and valleys in the wax set the needle and its attached

disk in vibration. These vibrations exactly reproduce the original vibrations that caused the groove. The vibration of the disk sets the air in front of the disk in vibration, and sound results. This sound will duplicate the original "ah," for it will be caused by the same kind of vibration.

It is possible to buy cardboard coated with wax, that you can put on your own phonograph table.

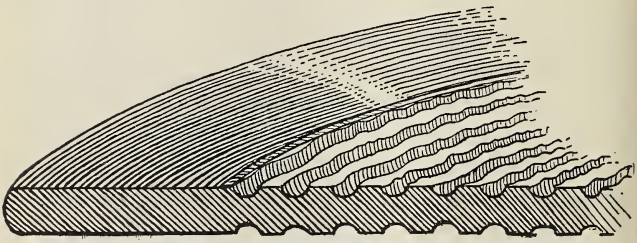


Fig. 128. A highly magnified section of a phonograph record

By first talking into the phonograph, and then playing the record produced, you can hear your own voice as it sounds to others. The results are far from perfect, but the experiment illustrates the principle very well.

326. Construction of a phonograph record. Commercially, the original record is made in a spiral groove, in a hard composition, using a modification of the method just described. This original record is then electroplated, and from this electroplate stampings are made that are sold for use. An enlarged view of a phonograph record is shown in Figure 128.

Phonographs are usually provided with a device for changing the speed with which the record rotates, thus changing the number of vibrations produced a second. As pitch depends on the number of vibrations a second, changing the speed with which the record is played not only alters the time required but changes the pitch of every note. As the pitch of all notes is changed in the same ratio, this makes no difference to the melody. The relative pitch of each note remains the same. Let the motor run down, so that the record plays very slowly. You will find that the pitch of all the notes becomes very low.

Phonographs also give an excellent illustration of the fact that one vibrating body can vibrate so as to give many different waves at the same time. The phonograph contains only one vibrating diaphragm, yet many notes are heard at the same time. It must be true that this diaphragm is capable of vibrating in many different ways at once. This gives many different pitches at the same instant.

Give a case of a vibration causing sound.
Give a case of sound causing a body to vibrate.
Why does a phonograph needle make a wavy groove in the wax when we speak into the phonograph?
How may this wavy groove be used to reproduce sound?
After a phonograph record has been used a great many times, it no longer reproduces the original sounds satisfactorily. Why?

CHAPTER THIRTY-EIGHT

LIGHT AND ITS REFLECTION

327. Light waves. *Light is a form of energy* to which our eyes are sensitive and by means of which we see. Our great natural source of light is the sun. Most artificial sources of light, such as the ordinary tungsten electric lamp, are solids that have been heated to a high temperature.

Light comes to the earth from the sun in the form of *waves*. Light waves have very short wave lengths. The waves in ordinary white sunlight are between 0.000027 and 0.000015 inch in length.

328. Light travels in straight lines. You know that you cannot see around a corner. This is because *light travels in straight lines*. Because of this fact, we can sight a gun or walk directly toward an object. We shall find later that light can be bent, as in passing through a lens. In a uniform substance, though, such as glass or air, light does travel in straight lines.

329. Light rays. In our experiments on light we shall often need to use a small bundle, rather than a mass, of light waves. This we can easily obtain by putting a screen with a small hole in it in the path of

the light. Only a small beam, or *ray*, of light can pass through this hole (Fig. 129).

What is the cause of light?
How long are light waves?
In what direction does light travel?
How do we know that light travels in straight lines?
How may light rays be bent?
What is a ray of light?
How can we obtain a ray of light?

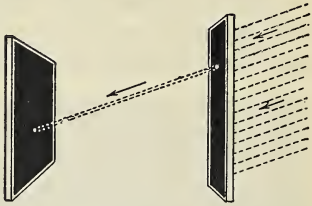


Fig. 129. Producing a light ray

330. Light: transmitted, reflected, absorbed. When a ray of light falls on an object, any one of several things may happen. Light falling on glass passes through it, or the light is *transmitted*. Light falling on a mirror is sent back in a new direction, or the light is *reflected*. Light falling on black velvet disappears. It is neither transmitted nor reflected; it is *absorbed*. In this case the energy of the light wave is changed into heat. Why, then, is a black velvet dress warmer than a smooth, white linen dress? Often all three of these effects are produced at once. Light falling on a dark-green leaf is 15 per cent reflected, 20 per cent transmitted, and 65 per cent absorbed.

331. Shadows. Stand in the sunlight and look at your *shadow*. Evidently it is caused by the rays

of the sun striking your body and being absorbed or reflected. A book, a tree — anything that is opaque — will have the same effect. Since light travels in straight lines, we can draw diagrams that will show just what the size and shape of a shadow will be.

Fig. 130. Emerald Lake, in the Canadian Rockies, acts as an almost perfect mirror. Turn this view upside down and examine it. How can you tell that it is upside down?

As the earth and the moon are opaque, they naturally cast shadows. We do not usually see these shadows, but sometimes they fall in such positions as to cause eclipses of the sun or moon. In that case the effect of the shadow is evident (Sec. **193**).

Explain what is meant by transmission, reflection, and absorption of light. Give two illustrations of each.

What causes a shadow? Why does the length of your shadow change?

Show by diagrams how eclipses of the sun and moon are caused.

332. What is a mirror? Have you ever seen yourself reflected in a pool of water? (Fig. 130.) Many years ago a pool of still water was the only mirror that our Indian girls had. Any smooth, polished surface that reflects light regularly can serve as a *mirror*. Everyone knows that glass, polished metals, and water may serve as mirrors. Ordinary mirrors are glass, coated on the back surface with silver.

333. Images in mirrors: the law of reflection. When light strikes a plane or a flat mirror, it is reflected, and, if the reflected ray of light enters your eye, you look along the ray and seem to see *behind* the mirror the object that really is in front of it (Fig. 131).

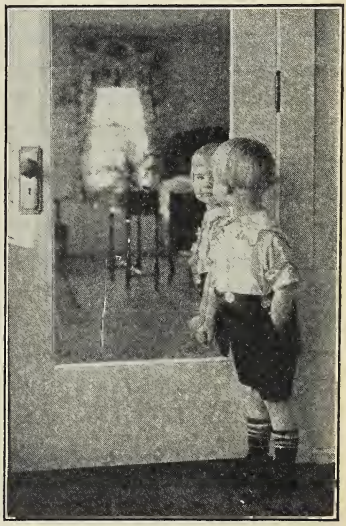


Fig. 131. An image in a mirror

Using a darkened room, allow a ray of light to strike a mirror. Knock two blackboard erasers together near the mirror to make the air over the mirror dusty. You will then see both the incident and reflected rays outlined in dust (Fig. 132). Notice that both rays make the same angle with the mirror.

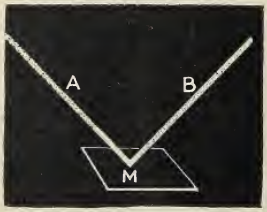


Fig. 132. A, incident ray; B, reflected ray; M, mirror

For reasons that you will understand later, it is better not to measure the angle between the mirror and the light ray. Instead, draw a line perpendicular to the mirror (called a normal), and measure the angles of incidence and reflection from that line (Fig. 133). You will find that *the angles of reflection and of incidence are equal.* This is the law of reflection. You use this law every time you place your tennis racket in position to strike a ball that comes to you on the bound.

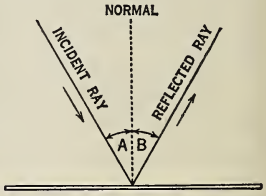


Fig. 133. The law of reflection. A, angle of incidence; B, angle of reflection

334. Misleading rays. In some ways the eyes are easily deceived. The eye never realizes that a ray of light can be bent by reflection, and so have its direction changed. It appears to the eye that

whatever direction a ray of light has when it enters the eye is the direction that it has always had.

Stand beside your mother in front of a mirror. A ray of light comes from the sun. It is transmitted through a glass window, enters your bedroom, is reflected from the wall to your face, from your face to the mirror, is reflected there and finally enters your mother's eye. Your mother looks along the

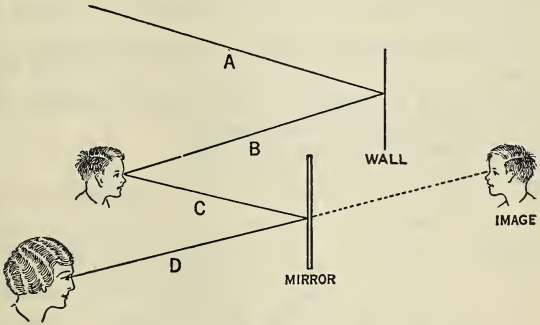


Fig. 134. Many times reflected ray. A, ray coming from source of light; B, ray reflected from wall; C, ray reflected from object; D, ray reflected from mirror

last direction that the ray had, and sees your face *behind* the mirror. Possibly she says, "Dear, you had better comb your hair again." Look at Figure 134 where the path of a many times reflected ray is drawn and you will see why this effect is caused. We call such a reflection in a mirror an *image*.

335. Mirrors are invisible. A good mirror is almost invisible, and a perfect mirror would be totally invisible. One of the authors of this book once owned a hunting dog who had never seen a mirror. The first time he was allowed in the house and saw his reflection in a large mirror, he made a dash for the other dog which he supposed his image to be. Of course he broke the mirror into fragments.

What is there in your kitchen that could be used as a mirror?
Why does the image in a mirror seem to be behind the mirror?
State the law of reflection. What use do you make of this law other than in science work?
Give a proof that a mirror is invisible.

336. The law of mirrors. We can find out just where the image in a mirror is if we draw two rays of light from the object in front of the mirror to the mirror. Draw the reflected rays and then imagine that both of these reflected rays enter an eye. This is shown in Figure 135. The eye looks along each ray and sees on each ray an image of the object. Since the image is seen on each ray, it must be

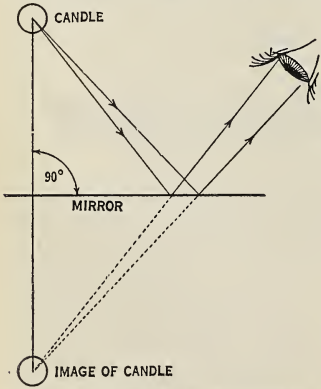


Fig. 135. The law of mirrors

placed where they cross. By geometry it is easy to prove these facts, but, since you have not studied that subject, perhaps you will believe them without formal proof.

In a plane mirror the image is *virtual;* that is, it has no real existence. It is as far away from the mirror as the object is in front, is of the same size as the object, is erect, but perverted. This means that the image is right side up, but that right and left have been exchanged. That is, when you lift your right hand, the image lifts its left hand. It is for this reason that printing seen in a mirror cannot easily be read. These laws you can prove for yourself by simple experiments, such as are given on pages 305, 306.

An object is four feet in front of a mirror. How far behind the mirror is the image? What are the characteristics of this image?
What is meant by an image? a virtual image? a perverted image? an erect image?
Draw an arrow in front of a line that represents a mirror. Draw the image of the arrow in the mirror, making it correct in both size and position.

337. Seeing "through" a stone. With the aid of four small mirrors and a cardboard box, you can amuse your friends by teaching them to see through a stone. Figure 136 shows the method of arranging your mirrors and box. If you are showing it as a trick, you must cover up the lower part of the box. A hand placed at A can be seen by a boy look-

ing through the tube. If, though, the boy is a keen science student, he will know that you are using mirrors even though he cannot see them. The hand at A will seem much farther away than it really is, and this will show him that reflection is taking place. Can you tell why this is true? Can you also tell how far away the hand will seem to be?

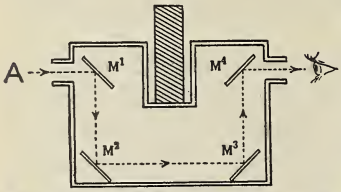


Fig. 136. Seeing through a brick. Where will the image be seen?

A common stage trick is to show a head placed on a table. No body is visible, yet the head talks. See if you can draw a diagram showing how, by the aid of mirrors, this is possible.

338. Curved mirrors. No matter what the shape of the mirror may be, the laws of reflection that you have learned always hold true. If you will apply these laws and locate one point at a time, you can always find where the image is located (Fig. 137).

Take a thin, polished plane metal mirror (a polished piece of tin will do), and while you look in it, bend the mirror. You will see how the image becomes distorted. Such curved mirrors are used in circus side

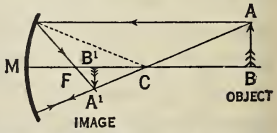


Fig. 137. Image in a concave mirror

shows to make you laugh at the image of fat men suddenly grown thin or short men grown tall.

339. Headlight mirrors. Some curved mirrors serve useful purposes. A searchlight has a curved mirror back of the light that reflects the light in such a way that the rays become almost parallel. A similar mirror is placed in the back of automobile headlights. Go home and look in the headlight of your automobile and you will see this curved mirror. The next time you go riding at night, notice how it reflects the light so as to send a beam of light along the road where it is needed, and prevents the light shining up on the sky where it would be wasted.

Cheap mirrors are sometimes made of glass that is not quite flat. Such mirrors show a distorted image.

How is a mirror made that will give an image of a fat man looking thin? of a thin man looking fat? a short man looking tall?

What is the shape of the mirror in an automobile headlight? What is its advantage?

Why must furniture mirrors be on plane glass?

Draw a curved mirror, and an arrow in front of it. By using normals and the law of reflection, draw the image of the arrow.

EXPERIMENT 56

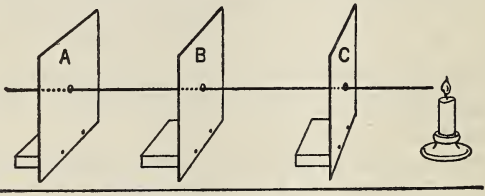
Question: Do light rays travel in straight lines?

Materials: Desk apparatus; three cards mounted on supports so that they stand upright (each card has a hole in the center; all these holes are to be exactly the same height from the table); straight wire 3 feet long; a light, either a candle or a lamp.

Directions: (*a*) Punch a small hole ($\frac{1}{4}$-inch diameter) in the center of each of three cardboards each about 8 x 10 inches. The backs of writing pads will serve the purpose. Tack each card to the end of a piece of wood about 6 x 4 inches so that the card stands upright, taking care that all the holes are *exactly* the same height from the table. (See diagram.) Support the light so that its center is opposite the center of the holes in the cards.

(*b*) Place one card (call this card A) three feet from the light. Look through the hole and you will see the light.

(*c*) Place a second card B a foot from A and between A and the light. Again look through the hole in A. You will probably not be able to see the light. Move B sideways until you



Experiment 56

can see the light. Put the long straight wire through the holes in A and B. 1. Where does the end of the wire pointing toward the light come to? 2. What does this show about the direction in which light rays travel?

(*d*) You have a third card C. Think over what you have learned about the way light rays travel. 1. Where can you put C, between B and the light, so that you can see the light when you look through the hole in A? Put C where you think it should be, and look through the hole in A. 2. Do you see the light? If you do not see the light, move C slightly from side to side until you do. Explain why you failed, if you do fail. Put the straight wire through all three holes. 3. Was your answer to question (*c*)2 correct?

Diagram: Show the three cards in position so that you can see the light and the wire going through and pointing to the light.

Conclusion: Answer the question.

Practical application: We make use of the fact that you have just learned in sighting a gun. It is also the reason why one cannot see around a corner.

EXPERIMENT 57

Question: Is the image in a mirror real or virtual, and what are its size and properties?

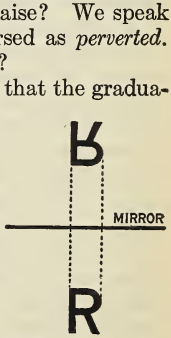
Materials: A mirror; a foot rule.

Directions: (*a*) Look in an ordinary mirror. The silver coating on the back of the mirror is opaque (will let no light pass through), yet we seem to see in back of the mirror a picture (image) of what is in front of the mirror. In a *real image* the rays of light actually do come from the place from which they seem to come. 1. Is the image in a plane (flat) mirror real? That is, do rays of light really come from the back of the mirror as they seem to do? 2. If the image is not real, what name do we give to it? (Text, Sec. **336**.)

(*b*) Stand in front of a mirror and raise your right hand. 1. Which hand does the image in the mirror raise? We speak of an image in which right and left are reversed as *perverted.* 2. Is the mirror image perverted? Is it erect?

(*c*) Put a foot rule close against a mirror, so that the graduation marks touch the mirror. How does the size of the image compare with the size of the object?

Diagram: Draw a line on a sheet of paper to represent a mirror. Draw on one side of this line the letter "R." Draw on the other side of the line the image of the letter as you would see it reflected in the mirror.



Experiment 57

Conclusion: Answer the question.

Practical application: Printing type is all cast perverted. When persons who are not familiar with type wish to read it, they find it difficult to do so. Reflecting the type in a mirror perverts the perverted image, thus bringing it the right way around and making it easy to read.

Experiment 58

Question: Where is the image in a plane mirror located?

Materials: A sheet of glass about six inches square to act as a mirror; a foot rule; two candles; a sheet of unruled paper.

Directions: (*a*) Mount the sheet of glass vertically by holding it in the clamp of a ring stand. The edge of the glass should rest on the table. Place the sheet of paper so that the glass crosses the center of the paper. Draw a line on the paper along the glass. This line you will use later to show the position of the reflecting surface (mirror). Darken the room and light one candle.

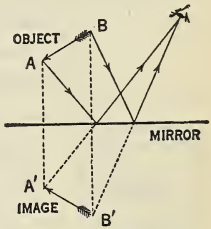
(*b*) You are all familiar with the fact that a sheet of glass can act as a mirror if it is brightly lighted from the front and has little light behind it. We have all seen this at home when we look out of a window into the night, and children often find it amusing when trying to look out of the windows of a moving railroad train at night.

Put the lighted candle on the paper about four inches in front of the glass. Draw around the candle on the paper a ring so that you can later locate the position of the candle. Place the unlighted candle back of the glass. Standing a little to one side, so that you can see the image of the lighted candle in the glass, move the unlighted candle back and forth until it is in just the same position as the image of the lighted candle. Draw a circle around its base (on the paper).

(*c*) Remove the paper and connect the centers of the two circles that represent the position of the candles. Measure the distance of the lighted candle from the front of the mirror and the distance of the image of the candle back of the mirror. How do these two distances compare?

(*d*) Your instructor will show you how to use a protractor. With its help, you will find that the line you drew connecting the candle and its image is at right angles to the mirror. Such a line, drawn at right angles to a reflecting surface, is called a *normal.*

Diagrams: 1. Show the apparatus set up ready for use. Mark on your diagram the position of object, image, and normal. 2. Draw on your paper a line to represent a mirror. Draw in front of the mirror an arrow, the head of the arrow being two inches, and the tail of the arrow being three inches in front of the mirror. Draw the image of the arrow.



Experiment 58

Conclusion: Answer the question, and state the law of plane mirrors. (Text, Sec. **336**.)

Practical application: Be ready in class to give at least four applications of the use of mirrors to ordinary life. You probably have one in your automobile for the use of the driver.

CHAPTER THIRTY-NINE

REFRACTION OF LIGHT

340. Spearing fish. Large fish are often caught by spearing them. The fisherman, standing in the bow of a boat, looks over its edge, and when he sees a large fish, he strikes at it with his spear. A curious thing is that he never aims the spear where he sees the fish. If he does, he will not strike the fish at all.

Fig. 138

It certainly seems peculiar to aim a spear at a point where you do not see a fish, and still strike it. To convince yourself that this is so, half fill a glass with water, put a spoon in it, and then look at the spoon from different directions. You will see that at the point where the spoon enters the water it looks bent (Fig. 138). You may have noticed the same thing when rowing. The

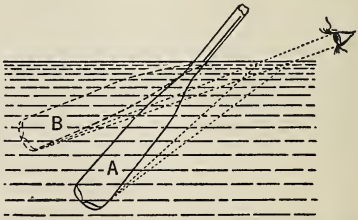


Fig. 139. Refraction of light. A, the actual position of oar; B, what the eye sees

oar seems to bend at the point where it enters the water (Fig. 139).

341. Refraction. This bending of light, when it goes from one substance to another substance of different density, is called *refraction.* It is caused by the fact that light does not travel at the same speed in water as in air. As soon as the wave of light starts to enter the water, the part that goes in first slows up, and this changes its direction of motion.

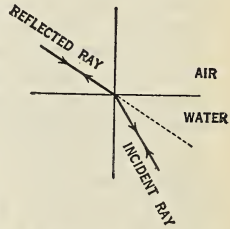


Fig. 140. A ray of light, passing from air to water, is bent or refracted

When you study physics, you will learn the laws of refraction. It is enough now for us to know that when a ray of light passes from a substance to a denser substance, it is bent toward the normal. When it passes from a dense to a less dense substance, it is bent away from the normal. Look at Figure 140 and you will see just what happens. You must memorize this fact, for you will need to use it when you study lenses.

Stand in the center of your kitchen, and look across the top of the hot kitchen stove. Observe that the straight lines of the wall no longer look straight, but seem to bend and twist. This is another effect of refraction. The heated air over the stove is of a different density from the cool air of the room, and so light passing through it is bent or refracted.

The hot air is continually changing its position, and also cooling. This changes the refraction from second to second and causes the quivering effect that you see.

In spearing fish should you aim above or below the point where you seem to see the fish? Draw a diagram to prove that your answer is correct.
Define refraction. What is the cause of refraction?
In going from a dense to a less dense material, in which direction is the ray of light bent?
How may a kitchen stove be used to show refraction?
Cheap window glass often causes objects seen through it to appear distorted. Why?
The bottom of a pond always looks nearer the surface than it is. Why?

342. Prisms. A glass prism is a triangular shaped piece of glass. Look at Figure 141 and recall the laws of refraction. You will see that the ray of light going through the prism must be bent as shown because it first passes from a less dense to a more dense material, such as from air to glass. It is therefore bent toward the normal. When it goes from a dense to a less dense material, as from glass to air, it is bent away from the normal.

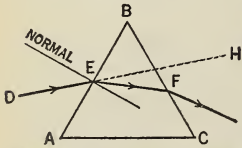


Fig. 141. A ray of light, D-E, on passing through a prism, A, B, C, is bent as shown

Now put two glass prisms together, base to base, as is shown in Figure 142, and notice the effect of the two prisms on light passing through them. Now round off the surfaces of

the prisms, and they will change into a lens. The rays of light will be converged or brought together.

343. Lenses. A lens is a *transparent body bounded by curves.* It is usually made of glass, but may be made of any transparent material. You can amuse yourself by making a lens of ice. Select a piece of clear ice, cut it roughly into shape with a knife, and then finish the lens by smoothing the rough places, using warm water on a cloth. Hold the ice in the sunlight and you will find that you have made a real burning glass. It may seem odd to find that an ice lens will draw rays of sunlight together to a point and burn you, but you know it is true because you have tried it. Here is one great advantage of the study of light: almost all experiments that are spoken of are of a kind that you can try for yourself.

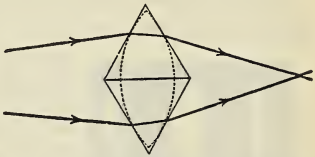


Fig. 142. Two glass prisms forming a lens

What is a glass prism?
What is its effect on light? Does it bend light toward or away from the base of the prism?
What is a lens?
Could we have a lens made out of salt? out of ice? Give a reason for your answer, and give a practical reason why ordinary lenses are not made of these materials.

344. Kinds of lenses. There are a great many kinds of lenses, but for our purposes we need consider

only those having curved surfaces that are parts of spheres. These spherical lenses are divided into two great classes — those thick in the middle and those thin in the middle.

A lens thick in the middle and thin at the edge is a *converging lens;* that is, it draws rays of light together. The common burning glass or reading glass, or the ice lens that you made, are examples of this kind of lens.

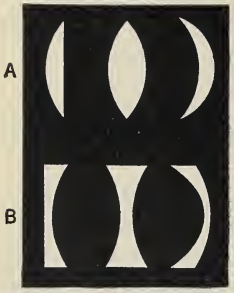


Fig. 143. Sections of lenses. A, three converging lenses; B, three diverging lenses

A lens thin in the middle and thick at the edge is a *diverging lens;* that is, it separates or scatters the rays of light passing through it. Certain eyeglasses are of this type, as will be seen later.

Figure 143 shows sections of several varieties of these lenses, but it is sufficient for our purposes to say that *converging lenses are convex lenses,* while *diverging lenses are concave lenses.*

345. Lenses form images. Pull the shades down so as to darken the room partially, and light a lamp. Near a wall farthest from the lamp, hold a convex lens between the lamp and the wall, moving the lens back and forth until you see a clear image of the lamp on the wall. This image is formed by rays of light being bent by the lens or refracted and *really* coming to a

point. The image is *real*, and such images, formed by the actual coming together of rays of light, are called *real images* (Fig. 144).

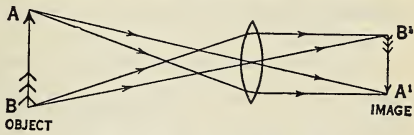
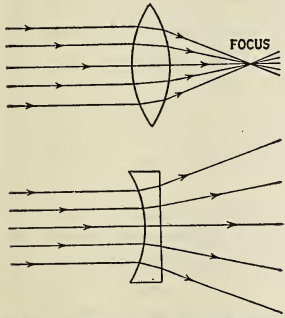


Fig. 144. A convex lens

346. Real and virtual images. Recall your work on mirrors. What you seemed to see back of the mirror was called an image. In this case, though, the image had no actual existence. No light really came from behind the mirror. Such images are called *virtual* or not real. Concave or diverging lenses form virtual images, as you will learn if you repeat the lamp experiment, using a concave lens. A real image can always be shown by allowing it to fall on a screen, while a virtual image cannot be so shown.



Figs. 145. How converging and diverging lenses affect light rays

The point where the rays of light cross after passing through a convex lens is called the *focus*. Through a concave lens, these rays would diverge. Figure 145 will help you to understand some of these facts.

What is the shape of a converging lens? of a diverging lens? What do these two words mean?

Show by the aid of a diagram the action of a convex lens on light. Is the image formed real or virtual? How do you know?
How can you tell whether any given image is real or virtual?
What is meant by the focus of a lens?

Experiment 59

Question: How do convex lenses affect rays of light?

Materials: A convex lens, preferably one of about six inches focal length; a bright light; a ruler.

Directions: (*a*) Use a wall opposite to a brightly lighted window as a screen to receive the image. Hold the lens in your hand and move it toward and away from the wall, until you see on the wall an image of the window. You will notice that only when the lens is in one particular spot is this image clear and distinct. What must the lens have done to the light rays coming from the window? Is the image on the wall real or virtual? erect or inverted? larger or smaller than the object (the window)?

(*b*) Darken the room. Place a bright light about six feet from the wall you are using as a screen. Place the lens between the light and the wall and move it back and forth until you get a sharp image. Put your results in the table.

Table

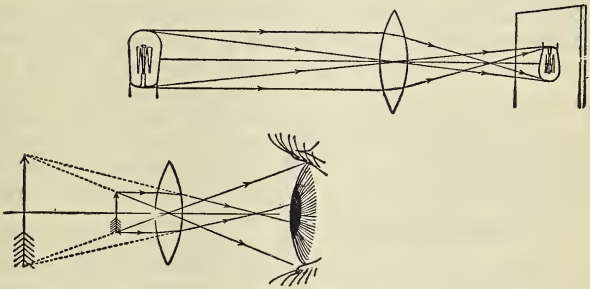
When the light was ..... inches from the lens, the image was ..... inches from the lens. The image was ..... When the light was, etc. Repeat three times.

(*c*) Place the lens two inches from the light and try to get an image on the wall. Move the light and lens until you are sure no real image is being formed. Stand about two feet from the lens, and look through it at the light. 1. If you should place a screen where the image seems to be, would the image appear on the screen? 2. Where is the image, is it real or virtual, and what is its size? Is it erect or inverted?

(*d*) Place the lens you used over the page of a book. Look through the lens. Move it closer to and farther from the book until you see a clear enlarged image of the words. This corresponds to what you found to be true in (*c*), and illustrates the use of a convex lens as a simple magnifying glass.

Diagram: Show the lens, light, and image.

Conclusion: As the light approached the lens, what happened to the image? 1. The image (approached, went farther from)



Experiment 59

the lens. 2. The image becomes (larger, smaller). 3. Why are the lenses on the best cameras mounted so that the distance between the lens and the film sensitive to light can be altered? 4. Answer the question.

Practical application: Lenses are used in cameras, in microscopes and telescopes, in eyeglasses, and in many optical instruments. If the lens used is a convex one, in every case it is used because it draws the rays of light together (converges them). There must always be a certain relationship between the distance of object and image from the lens if we are to get a clear image.

In cameras where the lens does not move, it is fixed at such a distance from the film that objects more than a few feet from the camera are almost in focus. The blurring of the

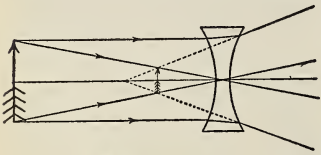
image is so slight that we do not notice it. If such cameras however, are used to take pictures of objects very close to the camera, this blurring becomes so great that the picture is useless.

Experiment 60

Question: How do concave lenses affect rays of light?

Materials: A concave lens of about six inches focal length; a bright light.

Directions: (*a*) Use a wall, opposite to a brightly lighted window, as a screen. Hold the lens in your hand and move it back and forth, until you form an image on the wall as you did in the last experiment. Look at the window through the lens. What kind of image do you see? Give its properties.



Experiment 60

(*b*) Place the light six feet from the wall and try to get an image on the wall by moving the lens back and forth as you did in the last experiment. 1. Can you get a real image on the wall? 2. What is the lens doing to the light rays?

(*c*) Hold the lens over the page of a book. Move the lens up and down, at the same time look through it at the printed matter on the page. What kind of image do you see? Why do we give it this name?

Diagram: Show the lens scattering rays of light.

Conclusion: Answer the question.

Practical application: Concave lenses scatter or diverge light. They are used in eyeglasses and optical instruments for this purpose.

CHAPTER FORTY

COLOR

347. Color and beauty. Color is one of the things that makes nature so attractive to us. We admire the soft pink of a rose, or the fiery orange of a sunset, and now we are to learn something of the cause of such beauty, and how to modify and use it for our benefit.

348. Whence comes color? We know that light comes from the sun as waves, and that these waves are of many different lengths.

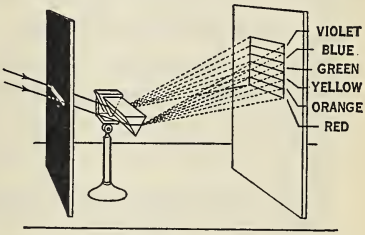


Fig. 146. A spectrum (rainbow) formed by passing a ray of light through a prism

Pass a strong white light through a narrow slit in a card and then pass the line of light produced through a glass prism. The result is shown in Figure 146. The white light, which was a mixture of many wave lengths, has been rearranged so that the shortest waves are at one end, the longest waves are at the other end, and the waves of intermediate length are between the other two. The most mar-

velous thing about the experiment is that the band of light produced is colored. It is called a *spectrum*. In the sky we often see the same thing, which is commonly called a rainbow. Look through any glass prism and you will see that the edges of objects are colored with the rainbow colors.

Since we have neither taken away any light nor added any light, all of these colors must have existed in the original white light. This proves that white light is really a mixture of colored lights. Our eye is so made that we do not see the separate colors, but only their combined effect.

Show by a diagram how a spectrum can be produced.
What is the difference between a spectrum and a rainbow?
How do we know that white light must contain red light?
If you should pass an entire spectrum through a convex lens, so as to combine all of the colors in one small spot, what color do you think the spot would be? Why?

349. Why is a rose red? We see a rose as red because white light, which really is a mixture of red, orange, yellow, green, blue, and violet lights, falls on the rose and all of this light is absorbed *except the red*. Red light is reflected by the rose and makes it look red to us. Really, then, the red rose is green and blue and all of the other colors except red. The rose will have nothing to do with red light. It refuses to live with it, but reflects it. The red rose is red because red is the only color that it reflects.

What would happen if we put a red rose in a green light? Green light contains no red, and if no red light falls on the rose, there is none for it to reflect. The rose will look *black*. The color of an object then depends on the light that falls on it.

350. Matching colors. A girl's mother buys her a bluish green scarf to match a silk dress. She buys it in a store lighted with electric lights. In this light it is a perfect match for the dress. When she gets home and examines it in daylight, the two colors do not match at all. Why? Because the light of the electric light is yellowish, although we think of it as white, and the color of the scarf changes according to the composition of the light that falls on it. For this reason colors must always be matched under the same light under which they will be used.

Why is a rose red? Under what conditions may a red rose look black?

Why may two colors that match in daylight not match under electric light?

A red rose is placed in a strong red light. What color will it be?

A painted rainbow is placed in a bright yellow light. What color changes will take place in the rainbow?

CHAPTER FORTY-ONE

HOW WE SEE

351. The eye. The eyeball is an almost spherical ball about one inch in diameter. Small as it is, it is one of the most precious possessions of mankind.

Here we do not need to know all about the anatomy of the eye. It is enough if we understand its general structure. The front of the eyeball contains the *cornea.* This is the slightly bulging, transparent portion of the tough outer coat of the eye. Back of the cornea is a curtain that is called the *iris.* This is colored, and determines the color of the eye. In the center of the iris is a hole that we call the *pupil.* The size of this hole varies in proportion to the amount of light that falls on the pupil. The brighter the light, the smaller the pupil. In this way the amount of light that enters the eye is kept within bounds (Fig. 147).

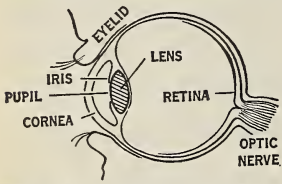


Fig. 147. The structure of the eye

352. How cats see. It is sometimes said that a cat can see in the dark. This is not true. In a completely dark room a cat can see no better than a

person. If you look at a cat's eye, you will see that the pupil is much larger than the pupil of your own eye. In a dim light the cat's pupil opens widely and admits enough light to enable the cat to see. In a dim light many animals see better than we do because the pupils of their eyes are larger.

353. The eye lens. Just back of the pupil is the *lens* of the eye. This tiny lens does just what the lens of a camera does. It bends the rays of light and brings them to a focus on the back of the eyeball, forming there a very small inverted picture of the scene at which one is looking. The back surface of the eye, on which this picture or image falls, is called the *retina*. In the retina the *optic nerve* or the *nerve of seeing* is spread out. The interior of the eyeball is filled with transparent jellylike substances that keep the eye in shape.

354. Our eye a camera. In a word, the eye is a *camera*. It has a lens, an adjustable stop or diaphragm, and a sensitive film. When you look at this page, your eye is acting just as a camera would. The eye lens is forming a small inverted image on the back of the eye which is called the retina. This image, falling on the optic nerve, carries a message to the brain, and we say that we see.

Students often ask why we do not see things upside down, if the image in the eye is upside down. The answer is simple. All seeing is education. The first time that a baby sees its mother he does not

know what the image means that is being telegraphed to his brain. Gradually the baby learns that a certain message means mother; and some other message means toy. It is a long time before he learns by experiment and experience what all the different messages mean. *Seeing is in the brain.* A trained observer will see far more than a beginner because he has learned better how to interpret his experiences.

As soon as we are taken away from our usual surroundings, our eyes often play us false. For example, we are accustomed to judge distance largely by the distinctness with which we see things. If we are in a climate where the air is clear, we underestimate distance.

Explain the use of the cornea, the iris, the pupil, the lens, the retina, and draw a diagram showing all these in position.
Why can a cat see better in a dim light than can a boy?
Why do we not see things upside down?
Why does a baby often grasp for things far beyond its reach?
Why does a diseased optic nerve cause blindness, even though the eyeball is perfect?

355. Eye defects. In a camera we adjust the distance between the lens and the film in order to bring near or distant objects into sharp focus. The nearer the object is to the camera, the farther the lens must be from the sensitive film in order to make a clear picture. In some cameras it is not

possible to make such an adjustment of the distance between the lens and the sensitive film, and such cameras cannot make a clear picture of very near objects.

In the eye we cannot vary the distance between the lens and the retina, so we resort to another plan. A band of muscle that passes around the lens is provided. By tightening this muscle, the shape of the lens is changed. This change in the shape of the lens does the same thing in the eye that altering the distance between the lens and film does in the camera. It makes the image fall on the retina. The more we squeeze the muscle, the more convex the lens becomes, and the better we can see near objects. As we grow older, this *power of accommodation* lessens, and we must use eyeglasses.

356. The eyeball is too short: farsight. Sometimes the eyeball is misshapen. If the eyeball is too short, the eye muscle cannot squeeze the lens hard enough to make a sharp image on the retina. The image is blurred, and sight is imperfect. Curiously this defect may exist during a lifetime, without the knowledge of the sufferer. No one knows just what his neighbor sees. The sufferer may never know that his own eyesight is defective. Many a pupil has been scolded for inattention to work on the blackboard when the truth was that he could not possibly see well enough to read what was being written, nor did he know that anyone else could see any better than

he could. The remedy for this condition is the wearing of convex glasses. These, in effect, bring the image closer to the lens and thus cause it to fall on the retina (Fig. 148).

357. Nearsight. Sometimes the opposite defect exists. The eyeball is slightly too long, so that the image falls in front of the retina. This defect is helped by the use of concave glasses. These diminish the convergence of the light rays and cause the image to fall farther back. These two defects, known as nearsight and farsight, are common (Fig. 148).

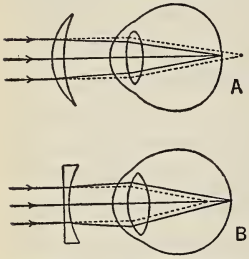


Fig. 148. A, farsight and its remedy; B, nearsight and its remedy

Other irregularities in the shape either of the lens, the retina, or the eyeball, bring about various defects of vision. They may be helped only by a skilful *oculist* who will prescribe specially ground lenses.

358. Power of accommodation. As we grow older, the eye lens hardens, and it becomes impossible to change its shape enough to bring near objects into focus. We say that the *power of accommodation* has diminished. Convex lenses will help this condition.

How does a camera focus on near objects? How does the eye?
What is the cause of nearsight? How may it be helped?

What is the cause of farsight? How may it be helped? What is the power of accommodation? Why does it diminish as we grow older?
How is it possible for a man to suffer from nearsight and yet never know it?

359. Care of our eyes. Nature has done her best to protect the eyes. They are set in a deep, bony socket so as to avoid injury from blows. This socket is lined with fat and smooth tissue so that the eye turns easily in its socket. Muscles are provided to move the eye in various directions. An eyelid is provided to close over the eye in time of danger, and to keep light out while the person is sleeping. Eyebrows and eyelashes are provided to protect the eyes from any foreign matter that might otherwise enter the eye. The tear glands secrete a liquid to wash the surface of the eye, keeping it clean and moist. All this Nature has done for us. For our part, we should never read in a dim light nor in too bright a light. Try to prevent foreign objects from entering the eyes. Use glasses when necessary. Never overtire the eyes, and do not read when lying down. Hold the printed page at the correct distance from the eye (about thirteen inches). In short, use the eyes with the same consideration that one would give an expensive camera. And, above all, when anything impairs the vision, go to an oculist at once and have it attended to.

Some students go through school doing poor work because of poor eyesight. It often happens that these

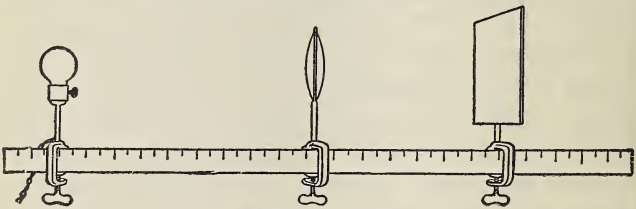
students do not know that their eyesight is poor. This is possible, because there is no way of their knowing what others see. If the blackboard work does not appear perfectly sharp and distinct to you, have your eyes tested in the school clinic. ***Poor sight may mean failure in life.***

Why are our eyes set in deep sockets? Why are these sockets lined with fat?
What is the use of the eyelashes, the eyebrows, and the eyelids?
Name three things that may injure the eyes, and explain the harm that each may do.

EXPERIMENT 61

Question: How are eyeglasses of use to nearsighted and farsighted persons?

Materials: A four-inch, focal length, convex lens to represent the lens of the eye; feebly converging and diverging lenses; bright light; long ruler; mounts for the lenses; and a movable screen to receive the image, arranged as in the diagram.



Experiment 61

Directions: (*a*) Place the light about three feet from the screen. Place the lens that represents the lens of the eye between the light and the screen. Move the lens back and forth until you have a sharp image of the light on the screen.

This represents a rough model of a normal eye, the screen representing the retina. Mark the positions of lens and image on ruler, so that you can replace them in these positions.

(*b*) Without moving the light or lens, move the screen back a little. The image on the screen will blur. 1. What name do we give to eyes if the screen (retina) is too far back? Place in front of the lens representing the eye lens the feebly diverging concave lens. What happens to the image on the screen? You may have to move the screen a little to get the image sharp, but it will still be back of its original position. 2. Why is such a lens used to help ..... sighted persons?

(*c*) Move the screen a little nearer to the lens than it was in (*a*), thus shortening the eyeball a little. 1. What name do we give to eyes that have this shape? Once more the image will blur. 2. What has happened to the image? Place the feebly converging lens in front of the eye lens. 3. What happens to the image? 4. Why are concave lenses used to aid ..... sighted persons?

A small black card having a half-inch hole punched in it may be placed next the eye lens in the experiment above (*c*)3. This will represent the pupil of the eye. Its effect will be seen in making the image sharper or fainter.

Diagram: Show both nearsighted and farsighted eyes, and how lenses may be used to improve these conditions.

Conclusion: Answer the question.

Practical application: Other defects of the eye may exist, and specially ground lenses may be required to correct these troubles. Always go to a competent oculist to have your eyes examined. Eyes are too precious to be trifled with or ignored.

CHAPTER FORTY-TWO

SOME OPTICAL INSTRUMENTS

360. Images, real and virtual. Before we discuss a few of the many uses of lenses, be sure that you understand real and virtual images (Secs. **345, 346**). A *real image* is one that can be caught on a screen, while a *virtual image* is one that only seems to exist. The image on the retina of the eye is real, while the image in a plane mirror is virtual.

Put a converging lens in the sunlight, and notice that the light is brought to a focus at a point a certain distance from the lens. Measure this distance. This is called the focal length of the lens. The focal length of the lens of the eye is about 0.6 inch. The more curved the lens, the shorter is its focal length.

361. The camera. Place a lighted lamp on a table in a darkened room. Holding a converging lens in your hand, move it back and forth near the wall of the room until you have formed a sharp real inverted image of the lamp on the wall. The image is much smaller than the lamp. Move the lamp nearer to the wall and again focus the image on the wall. You will see that the image is larger and farther from the lens. The shorter the focal length of the lens, the smaller the image of the lamp and

the lens must be nearer to the wall to produce a sharp image. This is the principle of the camera.

To make a camera, put a lens in the front of a light, tight box; put a sensitive film in the back of the box, add a device for moving the lens back and forth, and the camera is ready for use. Some cameras have lenses of such short focal length that it is not necessary to move the lens, unless to take objects that are very near. Such cameras are called fixed-focus cameras.

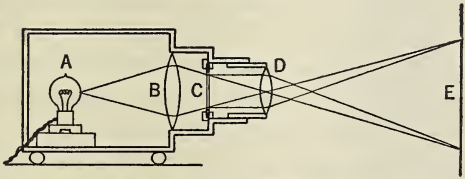


Fig. 149. The steropticon. The condenser lens B converges light rays on the lantern slide at C. The objective D forms an enlarged image of the lantern slide on the distant screen E

What is a real image? a virtual image? Where have you seen each?
What is the principle of the camera?
What is a fixed-focus camera?

362. Stereopticon. One of the most beautiful forms of photography is the lantern slide, as it is projected on the white screen of the motion picture. A glance at Figure 149 will show the optical arrangement used in the *magic lantern* or *stereopticon*. The light is at A, and at B is placed a condensing

lens that concentrates the light on the lantern slide C. The projecting lens, used to focus the picture, is at D. This is a similar case to that shown in Figure 144. The lantern slide is the object, and light going through it is focused at E. It is the exact opposite of a camera; the position of object and image has been changed.

363. Persistence of vision. On a dark night, ask a comrade to swing a lighted lantern rapidly around his head while you watch the light. A curious sight will be observed. You will see a circle of light. It takes a small fraction of a second for you to see the light and another small fraction of a second for the impression to die away. If the lantern is swung fast enough for the light to make one complete circle and return to its original place before the impression in the eye dies away, you will have each impression of the light renewed before it has time to disappear, or you will see a circle of light. This *persistence of vision* is the foundation of motion pictures.

364. Motion pictures. A motion-picture camera carries a lens and a film just as does a camera. The shutter of the former, however, is arranged in a different way. When the camera is cranked, the shutter opens and the film is exposed. Then the shutter closes, a claw drags the film along the distance of one picture, the shutter opens again, and another exposure is made. The film moves only while the shutter is closed. In this way sixteen

exposures a second are made. These tiny pictures differ very slightly from one another (Fig. 150), because the objects will have moved very slightly between the exposures. This film is developed and a positive film is made from it. This positive is the film that is employed in the motion projector.

Courtesy Paramount Publix Corp.

Fig. 150. On the screen all these pictures will blend together and show Maurice Chevalier turning naturally

365. Motion projector. The parts of the motion projector are the same as those of the stereopticon: a light, a condenser, and a projecting lens. The projector also contains a mechanism similar to the one in the motion camera, or a device for moving the film forward, and a shutter to cut off the light from the screen while this is being done.

One picture is shown, then the shutter cuts off the light and the film moves forward one picture. This motion of the picture cannot be seen, as the shutter darkens the screen. You might expect to notice the dark screen, but persistence

of vision shows you the picture on the screen even if it is not really there. As soon as the picture has been moved forward one frame and has come to rest, the shutter opens and once more a picture is seen on the screen. This is repeated sixteen times a second. The pictures all blend together in the eye, and you seem to see objects in motion.

If the projector moves the pictures forward too slowly, the image will almost die out in the eye before a new image takes its place. The picture will then appear to move in a jerky manner. If the projector is speeded up, all objects on the screen seem to move at a whirlwind pace.

It is possible, as you probably have seen, to produce all kinds of weird effects in motion pictures. By running the picture backward, all motion seems to be reversed, as when a man after diving, rises from a pool, sails up through the air feet first, lands on a springboard and, running backwards, disappears. If, while taking a scene, the camera is stopped for an instant, one of the actors steps to one side, and the camera then is run again, the actor on the screen will seem to vanish with no clue as to how it is done. By printing from several negatives on one positive film, a picture is obtained that is a combination of many exposures. As many as eight pictures are combined in one positive film to produce the effect shown in a certain play of Moses in which he divides the waters of the Red Sea.

What are the necessary parts of the stereopticon?
What is the use of each part?
What is meant by persistence of vision?
How does a motion-picture camera differ from the one in ordinary use?
Explain the operation of a motion-picture projector.

366. Magnifying glass. In order to see a distant object more distinctly, we move it closer to the eye so as to produce a larger image. We cannot bring it very close, however, for if we do, we cannot focus the image and we see only a blur.

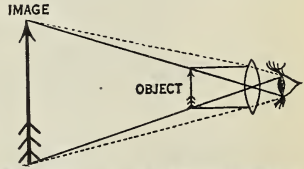


Fig. 151. A simple magnifying glass

To overcome this, we use a converging lens. Figure 151 shows what happens. The rays of light from the object travel as shown, and we see an enlarged image of the object. By increasing the curvature of the lens used, that is, by using a lens of short focal length, we increase the magnification.

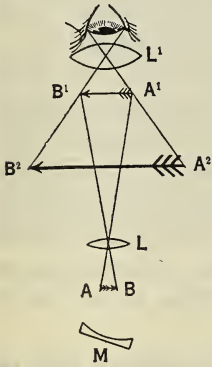


Fig. 152. A compound microscope

367. Compound microscope. In the compound microscope, which gives a greater magnification than the simple magnifying glass, two lenses are used to produce two magnifications. These

lenses and the path of the light rays are shown in Figure 152.

One lens L, called the objective, forms a real enlarged image A^1B^1 of the object AB. The eyepiece lens L^1 is a simple magnifying glass, and forms an enlarged virtual image A^2B^2 of the real image A^1B^1. These two magnifications result in our being

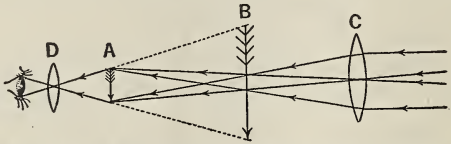
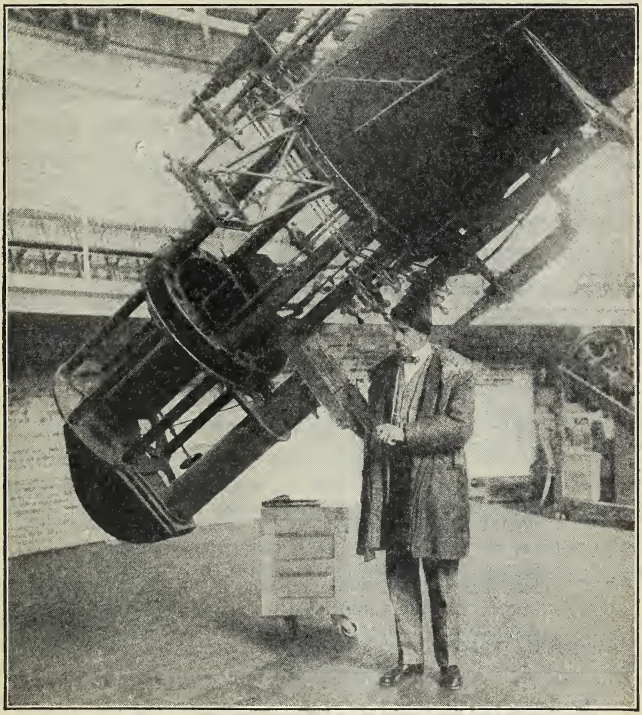


Fig. 153. The telescope. Light rays from a distant object pass through the objective C and form a small inverted image at A. This image is magnified by the eyepiece D, forming a new image at B. This is the image we see

able to see very small objects, such as bacteria. The mirror M is used to throw light through the object.

368. The telescope. In a telescope, one lens called the *object glass* forms a real image of a distant object (Fig. 153). The eyepiece D magnifies this real image and forms a virtual image B. This image is inverted. In the great Yerkes telescope (Fig. 154), the diameter of the object glass is forty inches and its focal length seventy-eight feet. This immense glass gathers so much light that even a very faint star gives a bright image.

In a terrestrial telescope, another lens, or pair of lenses, is added to the telescope. The effect is to



Courtesy Yerkes Observatory

Fig. 154. This large telescope is in Yerkes Observatory, Williams Bay, Lake Geneva, Wisconsin

invert the inverted image, and this brings it right side up. Figure 155 shows the path of the light rays through such a telescope.

In microscopes, telescopes, and similar optical instruments, some provision must always be made for focusing; that is, for making the image sharp. This is necessary because the position of the image depends on the distance of the object from the lens. Examine an opera glass or a field glass, and you will see that by means of a rack and pinion, the distance between the eyepiece and the objective can be changed.

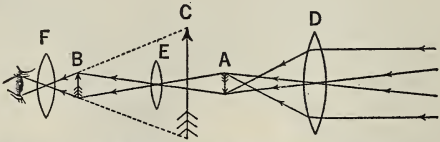


Fig. 155. The terrestrial telescope. The addition of another lens inverts the image, and we see the object erect. Light rays from a distant object pass through the objective D, forming a real image A. The second lens E inverts this image, forming a new erect image B. This is magnified by the eyepiece F, forming the image C. This final image is virtual, erect, and larger than the object

Explain the principle of a simple magnifying glass, often called a reading glass.

What is a compound microscope? For what is it used?

What are its advantages?

Explain the construction of the Yerkes telescope.

How is the image in a terrestrial telescope made erect?

CHAPTER FORTY-THREE

HEAT

369. Energy comes from the sun. We know that at least three kinds of energy reach us from the sun: light, heat, and chemical energy. We know this because we see by means of the sun's light; we are warmed by the sun's heat; and the sun's chemical energy fades the colors in our carpets, tans our skin, and makes it possible to take the photographs that we treasure as records of our happy summer trips.

370. Waves have energy. From the studies of many scientists we have found that the light, heat, and chemical energy of the sun reach us as waves. The difference between the light wave that falls on our eye and makes it possible to see, and the heat wave that falls on our hand and causes it to feel warm, is the wave length (Sec. **300**).

371. Length of heat waves. Light waves are from .00040 mm. to .00065 mm. long. That is, on the average, it would take about 1000 light wave lengths to equal the diameter of a hair $\frac{1}{50}$ of an inch thick. Heat waves from the sun are longer. Their wave length averages about 0.2 mm. Remember this: while this energy is coming to us from the sun, it is not heat or light, but a *wave motion.*

Give the proofs that we receive light, heat, and chemical energy from the sun.

When potatoes sprout in a dark cellar, the sprout is white. When taken into the light, the sprout turns green. Why?

In what form does heat energy come to us from the sun?

What is the difference between light waves and heat waves?

How do we know that heat waves from the sun have energy?

372. Sources of heat. When you step from the shade into the bright sunlight, you at once become aware that the sun is one of our most important sources of heat. Distant as it is, it sends out more heat than is obtained from any other source. Without it, life on this earth would be impossible, for plants would not grow, and the earth everywhere would be colder than the Arctic regions.

Another important source of heat is the burning of fuel, as coal, wood, and gas. These, however, do not produce heat until they oxidize in the air. This source of heat is therefore really due to chemical energy.

373. Mechanical productions of heat. Many forms of mechanical action also produce heat. Savages in many parts of the world obtain fire by rubbing one piece of wood against another. If the bearing on the axle of a railroad car fails to have sufficient oil, friction will develop so much heat that the cotton waste with which the bearing is stuffed may catch fire, Such a condition is called a "hot

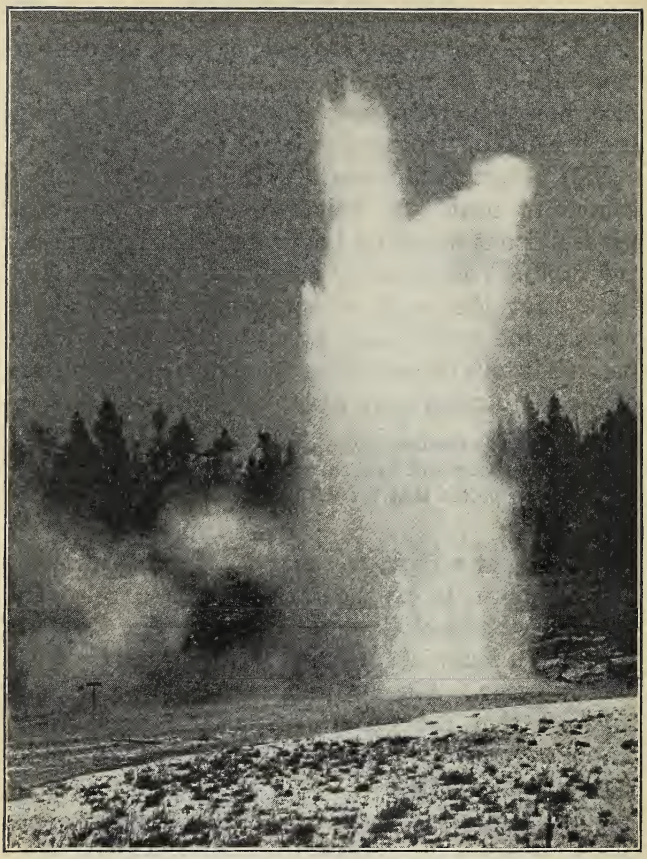
box." The train stops and cannot continue its journey until the bearing is cooled and re-oiled. Notice, also, how a bicycle pump when used becomes very hot because of the compression of the air particles.

374. Heat in the earth. The earth itself is a source of heat. In Yellowstone Park, hot-water geysers spout steaming hot water high into the air (Fig. 156). Volcanoes, from which flow molten lava, show that the earth is hot inside. Little use is made of the earth's heat, but its study is interesting because it tells us something of what the past history of the earth must have been.

What causes the heat given out by burning wood?
Give an example of heat caused by friction.
Give two proofs that the earth itself furnishes us with heat.

375. Heat a form of energy. If you hammer a block of iron, it expands and becomes hot. The weight of the block does not alter, showing that *heat cannot be a material substance*, nor does any chemical change occur. The iron block is made up of small particles that are called *molecules*. These are in motion. When the iron is hammered, its molecules have a faster motion.

376. Molecular motion. Hammering an iron block causes it to expand, because the iron molecules are set into more rapid vibration and strike one another harder. This causes them to move away from one another, increasing the space between them



Courtesy Union Pacific Railway

Fig. 156. Grand Geyser in Yellowstone National Park throws a column of water and steam 200 feet into the air

and so expanding the iron. This increased motion of the molecules also causes the block to become hot. Heat, then, is this *energy of molecular motion.* The faster the molecules move, the hotter is the body.

377. Conservation of energy. Careful experiments have shown that energy can be transformed, but can neither be created nor destroyed. This is known as the Law of the Conservation of Energy, which is one of the fundamental laws of nature. When the iron block is struck, heat is created. The energy of your muscle only is transformed into energy of heat. Heat, then, is *one form of energy.*

Why does a block of iron expand when it is heated? Why does it become hot?
Define heat. Why do we call heat a form of energy?
When wood burns, heat energy is set free. What is the source of this energy?
State the Law of the Conservation of Energy.

378. Measuring heat. To measure heat we must have some unit. The one generally used by engineers is the *British Thermal Unit* (*B.T.U.*). This is the amount of heat required to raise one pound of water one degree Fahrenheit. One pound of good dry coal when burned gives about 14,000 B.T.U.

A smaller heat unit, called the *calorie,* is used in scientific work. There are 252 calories in one B.T.U.

Persons who are on a diet often are conerned about the number of calories contained in the

food they consume. This calorie is a still different unit. It is called a large calorie, and is abbreviated to a capital C. It is equal to 1,000 small calories. We shall make little use of these units in our work, but it is interesting to know about them. The next time you go for a ride with your father, you will possibly astonish him with your knowledge if you tell him that his automobile is burning gasoline, one pound of which will give him 20,250 B.T.U.

379. What heat does. Heating a body causes many changes in its properties, such as changes in temperature, size, or physical state (solid, liquid, or gas). It can also cause a current of electricity to flow through a wire, as well as produce important chemical changes. Some of these heat effects we shall study in the chapters that follow.

Define B.T.U.
One pound of good coal should furnish how many B.T.U's.?
Why is the unit called a calorie used? How many calories in one B.T.U.?
Name three effects that may be caused by heating a body.

CHAPTER FORTY-FOUR

SOME EFFECTS OF HEAT

380. Expansion. One common effect of heat is *expansion*. When mercury is heated, it expands, and this property of expansion is used in making thermometers (Sec. **218**). An iron ball that will just pass through a hole in an iron plate expands when heated and will no longer pass through the hole (Sec. **215**). Hot water poured into a thick glass bottle usually cracks it, for heat expands the inside of the bottle while the outside remains cold. This unequal expansion breaks the bottle (Sec. **216**). A glass stopper sometimes sticks fast in a bottle. If the neck of the bottle is cautiously heated, it expands, and the stopper can then be removed. But if it is heated too long, both the neck of the bottle and the stopper will expand, and nothing is gained. Iron wagon-wheel tires are made smaller than the wheel. After being heated, they expand, and then can be slipped into place. As the tire cools, it contracts and binds the rim firmly on to the spokes (Sec. **216**).

381. Unequal expansion: the thermostat. Different substances expand at different rates. Brass, for example, expands half again as much as iron under

the same rise in temperature. Many uses are made of this fact. Suppose that you wish a bell to ring when an oven reaches a temperature of 600° F. Make a bar of metal that is brass on one side and iron on the other (Fig. 157). At ordinary temperatures the bar is straight. As it is heated, the brass expands more than the iron, and so the brass side of the bar becomes longer than the iron side, and this makes the strip bend.

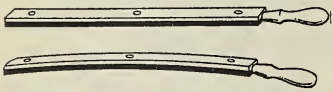


Fig. 157. The brass expands more than the iron and the bar bends

Look at Figure 158 and you will see how this fact is used. The strip A is fastened at the bottom, but the top is free. Heating the strip causes it to bend until the end A finally touches the point B. This allows a current of electricity to flow and ring a bell. As soon as the strip cools, the bar straightens, the two points A, B no longer touch, and the bell stops ringing. By adjusting the point B, it is possible to make the bell ring at any required temperature. Such a device is called a *thermostat.* Thermostats are used in many places, as in ovens and furnaces.

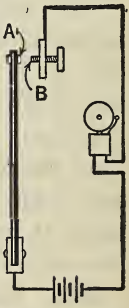


Fig. 158. The principle of the thermostat

The same device is also used as a thermometer. By fastening a bar and a string to the free end of the thermostat bar, a hand is made to travel

back and forth over a thermometer scale (Fig. 159).

What is the principle of the thermometer?
If a large glass marble is dropped into hot water, it will crack. Why?
How can you remove a stopper that is stuck in a glass bottle?
Explain the construction of a thermostat.
How may a thermostat be used as a thermometer?

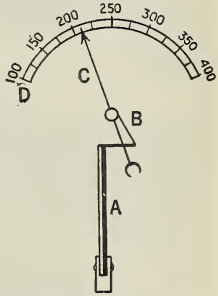


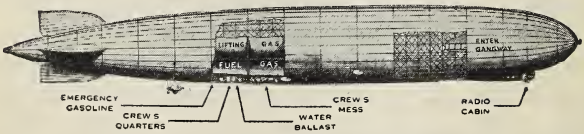
Fig. 159. Metallic thermometer as used on a bakery oven. One side of the compound bar A expands more than the other, causing it to bend. This pulls the cord B, moving the pointer C over scale D

382. Expansion of gases. Air, when it is heated, expands and causes wind. You have studied this before, but perhaps you can understand it better now. As the hot sun beats down upon the earth, the air is heated. There will then be less matter in each cubic foot of the air, for the air has expanded; that is, the air particles have been driven farther apart. Hot air is therefore lighter a cubic foot than cold air. It rises and cold air pushes in to take its place. This causes a *current of air* above the earth and *wind* on the surface of the earth.

383. Balloons. Not only air, but all gases expand when heated and contract (become smaller) when cooled. A balloon sailing through the air drifts into the shadow of a cloud. The gas con-

Courtesy Goodyear Tire & Rubber Co.

Fig. 160. The Akron soaring high over Washington, D. C.



Courtesy Goodyear Tire & Rubber Co.

Fig. 161. Shows the small gas balloons inside the shell

tracts, the balloon becomes smaller and drops. Ballast has to be thrown out or the balloon may be wrecked. Or, on a cloudy day, the balloon suddenly comes into sunlight. The gas expands, the balloon becomes larger and rapidly rises.

384. Dirigibles. In dirigibles, this change in size, due to expansion and contraction, is overcome by not quite filling the small gas balloons which are inside the shell that we see. Then as the gas expands and contracts, it does not affect the volume of the dirigible (Figs. 160, 161).

What is the cause of winds?
In a room having an open fire, there is an air current flowing toward the fireplace. Why?
Why may a cloud passing across the sun wreck a balloon if it is close to the earth?
Explain why this would not affect a dirigible.
Why does a hot-air balloon rise?

385. Freezing point. We all know that when water is cooled, that is, when heat is taken from it, it freezes. We do not all know though that this same thing occurs to other liquids when they are cooled. Mercury, alcohol, gasoline, all become solid, or freeze, when they are cooled enough. The temperature at which this freezing takes place is called the *freezing point* of the substance.

386. Melting point. When solids are heated, they turn to a liquid, or melt. Even metals, such as iron or gold, melt when they are heated enough. A few substances do not melt, but turn to a gas without becoming a liquid.

The temperature to which we must heat a substance before it melts is called its *melting point.* Some substances, as solder, do not melt at a definite temperature but become pasty, and it is difficult to

say just when they do turn into a liquid. It is this property of solder that makes it useful to the plumber.

387. Temperature table. The temperature at which substances freeze and melt is the same; that is, for example, ice begins to freeze at 32° F., and also begins to melt at the same temperature. A few are given in the table below:

FREEZING AND MELTING POINT OF SOME SUBSTANCES

	DEGREES FAHRENHEIT
Tungsten	5432
Steel	2370–2550
Glass	1800–2550
Silver	1760
Lead	620
Sulphur	239
Paraffin	about 130
Ice	32
Mercury	−40
Alcohol	−169.6

388. Evaporation. Many solids and liquids slowly change into a gas without being heated to the boiling point. We call this invisible change of a solid or liquid into a gas *evaporation*. Throw water on a warm stone and the water soon disappears. The water has changed into a gas or vapor.

Not only water, but ice, evaporates. Probably this will seem hard to believe, yet it must be so. If you hang out wet clothes on a cold day, the water first freezes and changes to ice. Then the ice evaporates, and the clothes become dry.

389. Boiling point of water. When water at sea level is heated to 212° F., it boils. That is, bubbles of steam, which are formed in the liquid, escape and set the water in violent motion. Alcohol, mercury, ether, each has a definite boiling point.

A knowledge of boiling points and freezing points is helpful in many ways. Thermometer manufacturers, by knowing about them, can construct instruments that will be serviceable in the freezing winter weather as well as in the summer. Automobilists use alcohol in their radiators in winter because it will not freeze at any temperature which they may experience. In summer, water, rather than alcohol, is used in the automobile radiators because it does not boil as easily.

TABLE OF BOILING POINTS

	DEGREES FAHRENHEIT
Zinc	1684.4
Mercury	674.6
Water	212
Alcohol	172
Ether	95
Liquid oxygen	−297

What is meant by the freezing point of water?
What is meant by the melting point of ice?
What is meant by the boiling point of mercury?
Give an experiment to prove that both water and ice evaporate.
Of what advantage to the automobilist are the facts regarding the boiling point and freezing points of alcohol and of water?

CHAPTER FORTY-FIVE

HEAT TRANSFER

390. Nonconductors and conductors of heat. If you put one end of an iron nail in a flame, the other end soon becomes too hot to hold. We therefore say that *iron is a good conductor of heat.* Put a match in a flame. The wood will burn down until it is too short to hold, but the end in your fingers does not become hot. This shows that *wood is a poor conductor of heat.*

To keep warm in winter, we must prevent the heat of the body from escaping. We therefore wear clothing that is a poor conductor of heat. To pick up a hot pan or kettle, we use a holder made of cloth which is a poor conductor of heat. This prevents the heat of the pan from reaching the hand.

We cook food in metal pots because metals are good conductors. The fire readily heats the pot, and so the contents are heated. We see, then, that both good and poor conductors are useful.

Put your hand on the top of your desk. It feels slightly warm. Put your hand on the iron leg of your desk. It feels cold. Both the desk and the desk leg have been in the same room, and therefore have the same temperature. Yet one feels cold to the touch and the other feels warm. To under-

stand this, think of their conductivity. Wood is a poor conductor; it does not conduct the heat away from your hand and the wood feels warm. Iron is a good conductor and rapidly takes heat from your hand. The iron therefore feels cold.

If you touch a newspaper, a teapot, a glass bottle, the seat of your automobile, will they feel cold or warm? Make up your mind about the probable answer; try the experiment, and then explain to yourself why they feel as they do, in spite of the fact that they really all have the same temperature.

What is meant by a good and what by a poor conductor of heat? Give two examples of each.
Why is the handle of a coffeepot often made of wood?
A marble slab and a wooden table both have the same temperature, yet the marble feels much colder than the wood. Why?

391. Water is a nonconductor. Cut a piece of ice of such a size that it will fit into a test tube. Wrap a piece of wire around the ice so as to make it heavy enough to sink in water. Drop it into a test tube and half fill the test tube with water. Hold the *bottom* of the test tube in your fingers, and heat the surface of the water (Fig. 162). You will find

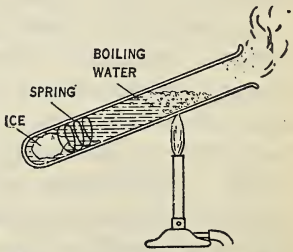


Fig. 162. Water is a nonconductor

that the surface of the water will boil, but the ice does not melt. Evidently, *water must be a non-conductor of heat*, yet we know that a pan of water put over a fire heats easily. Water must be heated in some other way than by conduction.

392. Convection. Put some sawdust into a beaker of water. Heat the water, taking care to put the flame well to one side and not under the center of the beaker (Fig. 163). The sawdust begins at once to rise at the point where the water is being heated, and to descend on the other sides of the beaker. This circulation of water distributes the heat through the water and is called *convection*.

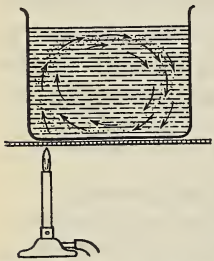


Fig. 163. Convection currents caused by heating water

393. Ocean currents. Ocean currents are caused by convection. The water in the Arctic regions is cold and sinks; the water at the equator is warm and rises. They exchange places, forming such currents as the Gulf Stream. Remember that since the Gulf Stream is a great body of warm water moving north, there must be a similar body of cold water near the bottom of the ocean flowing south.

394. Liquids and gases heated by convection. Liquids and gases are almost perfect nonconductors. They are heated by convection. The next time you go skating, wrap several turns of newspaper around

your body. You will be warm, not because of the paper, but because of the layers of air that are between the layers of paper. Since this air is a nonconductor and cannot readily escape, the heat of your body cannot pass through it. A fur coat is warm for the same reason. The long hairs of the fur entangle quantities of air, and it is really this air between the hairs and not the fur itself, that keeps you warm.

Give an experiment to prove that water is a nonconductor of heat.
Explain and name the process by which water is heated.
How are gases heated?
Why is a fur coat warmer than a cloth coat?

395. Radiation. If you stand in front of an open fire, you are warmed. How? Not by conduction, for air is a nonconductor. Not by convection, for the warm air is passing up the chimney, and not out into the room. You are warmed by a third method of heat transfer that is called *radiation.* The heat that you receive is called *radiant heat.*

Remember that heat reaches us from the sun as a wave motion, and that the energy of this wave is not heat until it strikes some material. There it ceases to be a wave, and its energy is changed into heat. That is radiant heat. Both light waves and radiant heat waves can pass through the glass windows of our houses. When the radiant heat wave strikes the walls of a room, its energy is

changed into heat, and this heat cannot escape easily through the glass window, for glass is a poor conductor of heat. Radiant heat, then, is not heat as we have defined it; that is, it is not the energy of the motion of molecules, but is the energy of a wave motion. For this reason a better name for it is *radiant energy* or *radiation.*

Explain the difference between radiant heat and ordinary heat.
How is radiant heat used to warm a room?
How do we know that an open fire is giving out radiant energy?
When sunlight is pouring into a room, the temperature in the room will be higher than the temperature of the outside air. Why?

396. Radiation can be reflected. As radiation is a wave motion, it can be reflected as light waves can. A mirror reflects light; it also reflects radiant heat. A lens refracts light; it also refracts radiant heat waves. Put a reading glass in a beam of sunlight and move it to and fro until you have a small, brilliant spot of light (Fig. 145). Put a piece of paper in this spot and the paper will smolder and finally catch fire. You have brought the radiant energy to a focus. We generally think of the heat of this spot as being due to light, but it is not; it is due to radiant heat.

397. Radiant heat. In California, near Los Angeles, where, in the summer time, there is almost continuous sunlight, a coil of blackened pipe connected with the water system is sometimes placed on

the roof of a house. We know that light is readily absorbed by black objects; naturally, we would expect radiant heat also to be absorbed. In fact, the water in the pipe soon becomes hot enough to be used as a source of hot water for domestic purposes.

398. Heat engine. By placing a number of mirrors in an inverted umbrella-shaped heater, one may obtain the same result. Radiant heat is reflected to a blackened boiler placed in the center of the heater. Water in the boiler will boil, and make steam which may be used to run a small engine. Such an engine is in use on the Ostrich Farm near Los Angeles.

Why would you expect radiant heat to be both reflected and refracted? Give proofs.

Give one useful method of employing reflected radiant heat.

Radiant-heat engines are cheap and easily installed. Why are they not used commercially?

399. Thermos bottles. On a bitter cold day, what is more comforting than a hot drink? At home you can easily obtain this, but suppose that you are on an automobile trip. How then can you have your hot drink? By taking a well-filled thermos bottle.

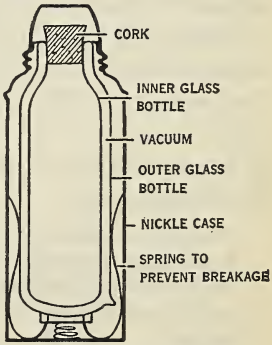


Fig. 164. Thermos bottle

A thermos bottle is a double bottle, with the inside silvered

and the space between the two bottles exhausted of air (Fig. 164). Fill such a thermos bottle with hot coffee. The coffee will not cool for some hours, for glass is a poor conductor and air is a nonconductor of heat. Radiant heat cannot escape, for it would be reflected by the silver mirror. You will see by the diagram that there is no chance for the coffee to cool by convection. The coffee, therefore, cannot cool except very slowly, due to a small escape of heat through the glass. The same bottle will keep water cold, for just as heat cannot escape from the bottle, heat cannot enter it.

400. Refrigerators. You have, of course, a refrigerator in your home. We do not intend to explain here its construction. Instead, we ask you to design a refrigerator. Remember that the first essential is to keep heat out of the ice box as completely as possible; second, to have a circulation of air inside the box; and third, to make a practical design. It would be useless to say, "A thermos bottle would make a good refrigerator." The cost of such a large bottle, its fragile character, the difficulty of putting food into it, would all prevent its use. Therefore make your design practical.

Explain the construction and the use of a thermos bottle.
A group of picnickers filled a fruit jar with ice, and wrapped the jar in many layers of newspaper. Would you expect the ice to melt rapidly or slowly? Explain.
Show your refrigerator design to your teacher.

401. The firecracker. Cut a firecracker in two lengthwise. You will see that inside is a small amount of gunpowder, and that this gunpowder is in a closed box, formed by the paper sides of the cracker and the clay plugs that close the ends of the box. Set fire to the gunpowder. It burns quickly but *no explosion occurs.* The burning of the powder sets free volumes of gases, but these do not cause an explosion unless they are confined in a small space.

402. Explosions. An *explosion* is the sudden rapid burning of some confined substance, with the formation of large volumes of hot gases. Since the gas is confined, its increasing volume causes greater pressure on the container walls. It is this gas pressure that finally breaks the walls of the confining vessel and causes an explosion.

403. Ether and air can explode. Ether is a very inflammable substance. Put four drops of ether into a six-ounce bottle. Let it stand, covered, until the ether has evaporated, and then put a match to the mouth of the bottle. The mixture of ether and air will burn so quickly that an explosion will occur.

Bore a hole in the bottom of a tin can. Place a few drops of ether in the can. Cork it, but not too

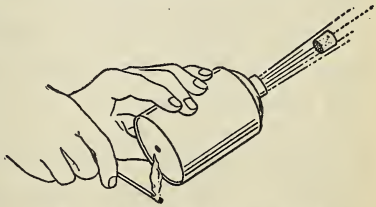


Fig. 165. A crude gas engine.

tightly, and put a match to the hole in the bottom (Fig. 165). The explosion will drive the cork across the room. In performing this experiment you have made a crude gas engine.

404. Automobile gas engine. We all enjoy riding in an automobile, and we ought to understand the principle of the gasoline engine that makes the automobile go. In the first place, we understand what causes an explosion. When we light a firecracker, the spark burns down the fuse quietly, then there is a sudden bang, and the cracker breaks open with a loud report.

405. How the automobile engine works. An automobile gas engine has a cylinder C (Fig. 166) corresponding to the tin can that was used in the last experiment. An *inflammable mixture* of gasoline and air is drawn into this cylinder through the inlet valve V. Gasoline is used instead of ether, as it is much cheaper. To set fire to the mixture use, instead of a match, an electric spark produced at the spark plug K. Instead of a cork being thrown across the room, the piston P is pushed down. The piston is connected to a crankshaft CS, and this shaft is connected to the rear wheels. The downward motion of the piston rotates the crankshaft and this rotates the

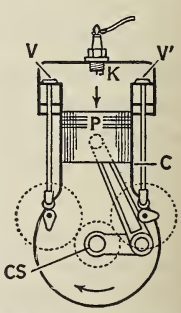


Fig. 166. Cylinder of an automobile engine

wheels. Two holes in the cylinder wall are filled with the inlet valve V and the exhaust valve V′.

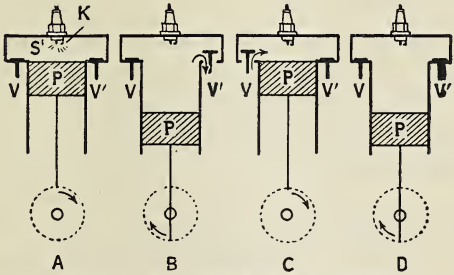


Fig. 167. Four cycles of a gas engine

In A the piston P is at the top of the cylinder, and the space S is filled with an explosive mixture. A spark at K ignites the mixture and the explosion pushes the piston down. This is the power stroke. At B the piston is rising and pushing the burnt gas out through the exhaust valve V′. This is the cleaning stroke. At C this piston is moving down and drawing the explosive mixture into the cylinder through the inlet valve V. This is the admission stroke. At D the piston is rising and compressing the mixture of air and gasoline. This is the compression stroke. The engine is now in the position A and all four processes are repeated

These open and close, one to admit the explosive mixture, the other to allow the burnt gases to pass out.

If you will study the caption of Figure 167, you will understand just what takes place in the automobile engine.

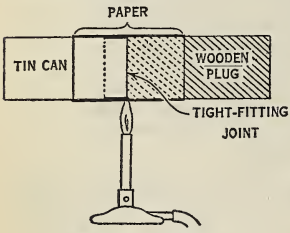
Since there are four distinct actions in such an engine, it is known as a *four-cycle engine.* Only one stroke in four is a power stroke. Early automobiles

had engines with only one cylinder. These cars had a very jerky motion, especially at low speeds. Since only one stroke in four was a power stroke, during three quarters of the time that the car was moving, the engine was turning over without delivering any power. That is, the engine gave the car a violent push (power stroke) and then the car rolled for a while under its momentum. Then the engine gave another push and this was continued as long as the car was running. To avoid this, cars now have engines with four, six, eight, or sixteen cylinders.

Experiment 62

Question: What is meant by heat transfer by conduction?

Materials: Cut a hole in the bottom of a baking powder can or some similar small metal can. Whittle a plug of wood of such a size that it just fits into the can. Drive the wooden plug tightly halfway into the can, and smooth the wood where it goes into the can so that you can wrap a piece of paper tightly around both. (See diagram.) The plug must fit the can tightly or the experiment will fail.



Experiment 62

Directions: (*a*) Wrap a piece of paper tightly around the plug and can, so that one half of the paper is on the can and one half on the wood. Use only one thickness of paper. Paste it down to the wood and tin. Place the plug in a Bunsen burner flame, so that the flame strikes the paper where wood and tin join. (See diagram.) As soon as you see any of the paper begin to scorch, take it out of the flame, allow it to cool,

and examine it. You will see that where the paper rested on the wood, it is scorched. Where it rested on the metal, it is not scorched. 1. Does heat pass more readily through wood than tin? 2. Why?

(*b*) Find a glass rod and a metal rod of the same diameter and length. Hold them side by side in a Bunsen burner flame. Which heats more quickly (conducts the heat to your hand more quickly)? 1. Is glass or metal the better conductor of heat? 2. Remembering that all matter is made up of small particles called *molecules,* explain how the heat is transferred from one end of the metal rod to the other.

Diagram: Show the apparatus of experiment (*a*) in use.

Conclusion: Answer the question.

Practical application: We make saucepans of metal, but stand hot dishes on mats of asbestos. Workmen while handling hot materials, use heavy gloves made of a nonconducting cloth.

Experiment 63

Question: What is meant by heat transfer by convection?

Materials: Desk apparatus; a large beaker; a handful of fine sawdust.

Directions: (*a*) Fill the beaker with water and throw in a little fine sawdust. Let it stand until the sawdust is thoroughly wet. Support the beaker on a large wire gauze, so that you can heat one edge of it, not the center. Place the Bunsen burner flame, turned low, under one edge of the beaker. Notice the currents in the water, as shown by the movement of the sawdust. The water at the bottom of the beaker becomes hot, this causes it to expand, thus becoming lighter and rising. These currents thus produced are called *convection* currents. 1. Why was the beaker heated on one side and not in the middle? 2. Why is there an upward current of air over a hot steam radiator?

Diagram: Show the sawdust in circulation (Fig. 163).

Conclusion: Answer the question.

Practical application: Caged birds are sometimes hung near the ceiling in a kitchen. They often show signs of acute distress from heat, although the cook appears to be cool. 1. Why is this? 2. Why does a baby crawling on the floor often feel cold when adults seated in chairs in the same room are comfortable?

Experiment 64

Question: What is meant by the transfer of heat by radiation?

Materials: A carbon filament lamp; electric current; radiometer.

Directions: (*a*) Light the lamp and put your hand close to it. Your hand will soon feel very hot because of the escape of heat from the lamp. You know that there is a vacuum inside the bulb, and you can see that the filament stands up by itself, and is connected to the lamp by two slender supports. 1. How do you know that the heat you feel does not reach your hand by conduction? by convection? 2. Explain how the heat does escape from the lamp.

Experiment 64

(*b*) Examine the radiometer. It is a bulb containing very little air. Inside it is mounted a windmill (vane). Each arm of the windmill is coated on one side with lampblack; on the other side it is bright. Place it in the sunlight and the windmill will revolve. This is another example of radiation. Radiant energy comes from the sun in the form of waves. These strike the black surfaces and are absorbed. They are reflected from the polished surfaces. This difference causes the vane to rotate. 1. Since there is a vacuum inside the radiometer bulb, how does the radiant energy get inside the bulb? 2. How do you know that neither conduction nor convection causes the rotation?

Diagram: Show the radiometer.

Conclusion: Answer the question.

Practical applications: Radiant energy passing through the glass heats cold frames. Milk cans are polished to reflect radiant energy. Place a piece of white and a piece of black cloth on a field of snow. 1. Under which cloth will the snow melt the faster, and why? 2. Why should you not polish the bottom of your teakettle? 3. Why are white clothes worn in tropical climates? 4. Heat may pass through glass, yet the glass remains cold. How can this be?

Experiment 65

Question: Why do we use thermos bottles on picnics?

Materials: A quart thermos bottle; a quart mason jar; two thermometers.

Directions: (*a*) Examine the construction of a thermos bottle. Someone in the class may have a broken inside glass piece that you can use. 1. Remember that the silvered surface will reflect radiant energy. How can heat enter the thermos bottle by radiation? Remember that the space between the two glass bottles is a vacuum, and that convection can occur only when there is some material present that can move. 2. How can heat enter the thermos bottle by convection? Remember that in conduction heat is transferred from particle to particle. 3. How can heat enter the thermos bottle by conduction?

(*b*) Pour a pint of water that has almost reached the boiling point into a mason jar and a pint into a thermos bottle. Take both pints from the same kettle, so that both are of the same temperature. Record the temperature of the water. Cork the thermos bottle and cover the mason jar with its glass lid. After thirty minutes take the temperature of the water in both. Explain why the water in the mason jar has cooled the faster.

(*c*) Repeat (*b*), using this time ice-cold water. Be sure to use the same quantity of water, and the same temperature in each case. Let both stand for thirty minutes, read the temperature, and record. If you have two thermos bottles, try (*b*) and (*c*) at the same time. Why did the water heat faster in the mason jar?

TABLE

	THERMOS BOTTLE	MASON JAR
Temperature of hot water at start of the experiment	.....° F.	.....° F.
Temperature of hot water 30 minutes later	.....° F.	.....° F.
Temperature of cold water at start of experiment	.....° F.	.....° F.
Temperature of cold water 30 minutes later	.....° F.	.....° F.

Diagram: Show the construction of a thermos bottle (Fig. 164).

Conclusion: Answer the question.

Practical application: Certain railroad tank cars have the same construction as a thermos bottle, but on a larger scale. They may hold 4,000 gallons. They are used to ship milk from distant points to large cities. The milk in these cars is cooled to a temperature of 38° F. After these cars have been 9 hours on the road, and have traveled 250 miles, the temperature may not have risen more than two or three degrees.

EXPERIMENT 66

Question: What is the source of the energy that provides power for an automobile?

Materials: Ether or high-test gasoline; bottle; dry sand.

Directions: (*a*) Put $\frac{1}{8}$ inch of dry sand in a dry, wide-mouth bottle holding about 8 ounces. Add one drop of ether from a medicine dropper. Put your hand over the mouth of the bottle and shake. The sand will aid in making a good mixture of the ether and the air in the bottle. It has no other use and is not necessary for the success of the experiment. Hold a lighted match near the mouth of the bottle. Note what happens. (Text, Secs. **404-405**.)

(*b*) Repeat (*a*), using two drops of ether, then three drops, then four, five, six, etc. Continue until you understand why you obtain such varying results. Record your results in the table.

Remember that if you prepare a mixture of air and ether and then set fire to it, the gas left in the bottle is not air. In some way, before each test, you must be sure that the bottle really contains air. Just how this may be done is left to your ingenuity.

TABLE

I used an eight-ounce bottle, added varying quantities of ether to it, and tried to burn the mixture. With—

1 drop of ether. The mixture.....
2 drops of ether. The mixture.....
3 drops of ether. The mixture.....
4 drops of ether. The mixture.....
5 drops of ether. The mixture.....
etc.

1. Why did your first mixture refuse to burn?
2. Which mixture gave a sharp explosion?
3. Why is there an adjustment on the carburetor of an automobile that controls the amount of gasoline fed to the engine?

Diagram: None is required.

Conclusion: Answer the question.

Note: If it is more convenient, you may use an easily volatile gasoline instead of the ether. A mixture of air and illuminating gas is also satisfactory.

Practical application: Every gas engine in use depends on the fact that certain proportional mixtures of air and an inflammable material burn so rapidly that an explosion results. Alcohol, benzol, gasoline, ether, oil — all may be used. Gasoline is ordinarily used in automobiles because it is cheap and satisfactory. Automobile engines have been made, however, that use alcohol, and others use illuminating gas. One engine, the Diesel, uses a heavy oil. An attempt is being made to use these Diesel engines in airplanes. If this is successful, it will be an advantage because it will limit the danger of fire that has caused the death of so many airplane pilots.

CHAPTER FORTY-SIX

MAGNETISM

406. Were early sailors timid? Why do you suppose that early man did most of his sailing close to the shore? He had good boats and the desire to explore, yet, if possible, he always sailed in sight of land. At sea, he had no means of determining the direction in which he was sailing, except by the sun and the stars, and these were often hidden by clouds. As a result, he had very strange ideas of the geography of the land and the sea. Ocean sailing was not safe until the invention of the compass.

407. Magnetism and magnets. Man began to know something about *magnetism* when he discovered that an iron ore, a black, shining mineral called *magnetite*, or *lodestone*, would attract iron filings, and that these iron filings would stick to the magnetite.

The next step was the discovery that when a piece of hard steel was rubbed on a piece of magnetite, the steel became a magnet. Finally it was found that if this artificial magnet were placed on a cork and floated on water,

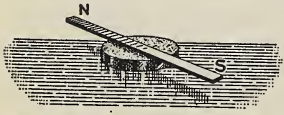


Fig. 168. The first compass

it always pointed north and south. This was the first compass (Fig. 168).

408. Artificial magnets. Today there are much better ways of making artificial magnets than by rubbing steel on magnetite. For a few cents one may buy a much better magnet than any that the old philosophers owned. Now let us try to discover some of the many interesting things about these magnets and magnetism.

How can you make a compass from a piece of magnetite?
How can you tell whether a piece of steel is a magnet or not?

409. Magnets have poles. Dip a small bar magnet into iron filings. Notice that the filings cling only to the ends of the magnet. In the middle of the magnet there seems to be no action. The points where the action seems to be greatest are called the *magnetic poles* (Fig. 169).

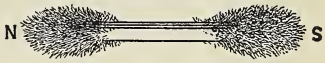


Fig. 169. Magnetic poles

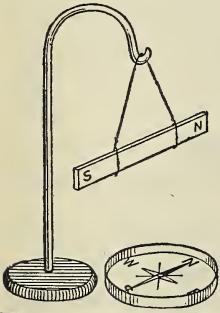


Fig. 170. A suspended magnet points north

410. Poles of the bar magnet. If the bar magnet is hung so that it is free to turn, it will always point north and south (Fig. 170). The end of the magnet that points to the north

is called the *north pole*, and the other end, that points to the south, is called the *south pole*. Such a suspended magnet is a compass. It would be awkward to carry such a suspended magnet; consequently, instead of suspending it, we balance the magnet on a point. Such a compass is in general use (Fig. 171).

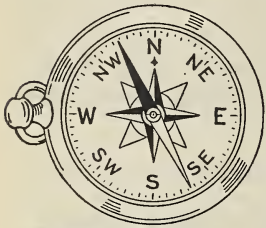


Fig. 171. A compass

411. Attraction and repulsion. Hang up two magnets, and, by noticing which end points to the north, find the north pole of each magnet. Mark these "N." Hang up one of these magnets and bring the north pole of the other magnet near the north pole of the suspended magnet (Fig. 172). The suspended magnet will turn, just as if there were a force pushing the two north poles apart. Repeat the experiment, using the two south poles. The same situation occurs. *Like poles repel* or push each other away.

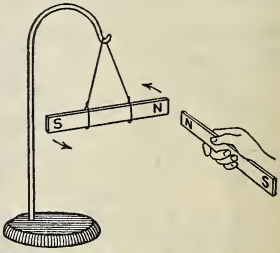


Fig. 172. The law of magnets

Now bring the south pole of the magnet near to the north pole of the suspended magnet. The two unlike poles try to come together. *Unlike poles attract each other.*

Place a piece of soft iron near the north and then near the south pole of the suspended magnet. In both cases the magnet attracts the iron. *Both poles of a magnet attract soft iron.*

These three facts are the fundamental laws of magnetism, and will be used many times.

How may you learn which is the north pole of a magnet? How many poles has a magnet? What are they named? Why are these names given to them?
Describe the construction of a compass. How can you make one?
What are the three main features of magnets?
Give an experiment to prove each of the statements that you made in answering the last question.

412. Magnetic influence. Place a steel needle on a sheet of paper held in the hand, and move a magnet around underneath the paper. You will see that the needle follows the magnet. *The magnetic influence passes through paper.* Try the same experiment with glass or a photographic film, and the same thing will happen. If, however, you place the needle on a sheet of soft iron, you will find that the needle no longer follows the magnet. *The magnetic force does not pass through iron.*

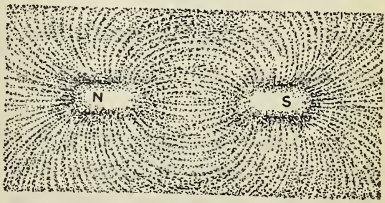


Fig. 173. The magnetic field outlined by iron filings

413. Magnetic field. Cover a magnet with a sheet of paper, sprinkle iron

filings on the paper, and tap the paper gently. You will see that the filings arrange themselves as is shown in Figure 173. Evidently this mysterious something that attracts iron filings to a magnet extends for some distance from the magnet. This arrangement of the filings shows that this influence is strongest at the poles, and passes from pole to pole in curved lines. This area, within which the magnet influences iron, is called the *magnetic field of force.* We say that the filings mark out the *lines of magnetic force.*

Move a very small compass along one of the lines of force indicated by a row of iron filings. You will see that the compass needle always places itself parallel to the line of force. The north pole of the compass always points toward the south pole of the magnet (Fig. 174). By using such a compass we can map out the lines of magnetic force.

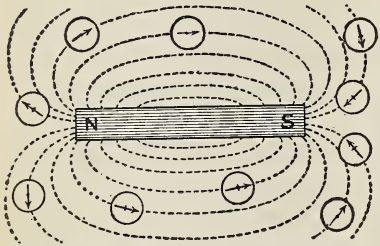


Fig. 174. Mapping the magnetic field

Try various arrangements of magnets, some of which are shown in Figure 175. In every case you will see that *a magnetic field exists around all magnets. Lines of magnetic force starting from like poles repel*

each other, and *lines of magnetic force starting from unlike poles attract each other.*

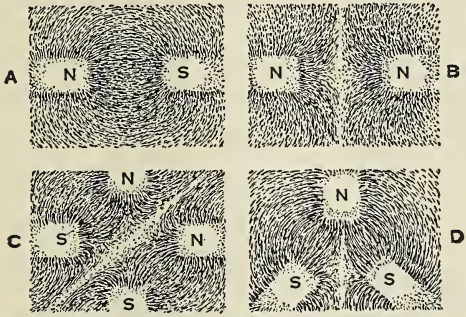


Fig. 175. Fields of magnetic force produced by magnets

How would you prove that the magnetic influence does or does not pass through paper? through glass? through soft iron?

Draw a magnet and show the magnetic lines of force that surround it.

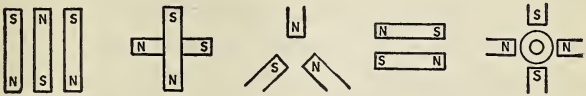


Fig. 176. Several experimental arrangements of magnets

Draw the lines of force in the magnetic field that would be shown by iron filings sprinkled around magnets arranged as shown above. The circles in the last diagram represent a heavy iron washer or ring.

How does a compass needle move when placed on a line of magnetic force?

414. The earth a magnet. A magnet tries to point north and south because the earth itself is a huge magnet. There must then be a field of magnetic force around the earth, and a compass needle tries to move so as to be parallel with the magnetic lines of the earth, or to point north and south (Fig. 177).

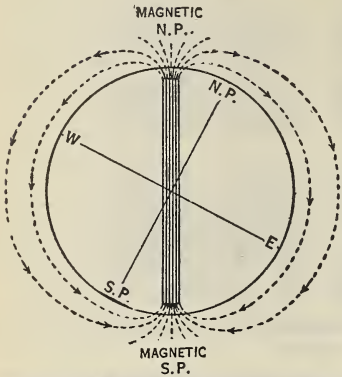


Fig. 177. The earth is a huge magnet

415. Earth's magnetic poles. The north and south *magnetic* poles of the earth are not, however, at the north and south geographical poles. In consequence the compass does not point exactly north and south. To make this plain, mark on an earth globe the north and the south magnetic poles. The north magnetic pole is located at longitude 96° 43′ west, and latitude 73° 31′ north, or about 1400 miles from the geographical North Pole, in the Hudson Bay region. The south magnetic pole is located in latitude 72° 25′ south and longitude 155° 16′ east (Fig. 178).

Chalk on the globe a few of the earth's magnetic lines of force. The meridians on the globe run north

and south, while the lines that you have chalked, the *magnetic* meridians, show the direction in which the compass needle would point. The angle between these two lines shows the variation between true north and the magnetic north. The government publishes, for the use of sailors, tables showing the variation from true north in various parts of the world.

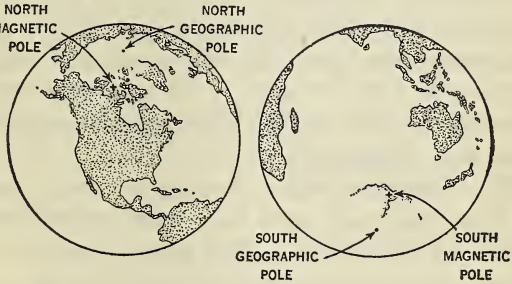


Fig. 178. The magnetic poles of the earth

If a compass is placed between the north magnetic and the geographical North Pole, you will see that in that part of the world the compass points *south.* Near Cincinnati, Ohio, the compass points true north. In the extreme northwestern part of the United States it points 20° east of true north, and in the extreme northeasterly part it points 20° west of true north.

416. The nonmagnetic ship. To find out in which direction the compass really points in different parts of the world, so that magnetic maps may be prepared for the use of sailors, the government built the nonmagnetic ship, the *Carnegie*. Very little iron was used in constructing this ship. The nails used were copper and the fittings were made of brass or bronze. This was necessary so that iron in the ship would not affect the reading of the compass. This ship was fitted out with the best compasses to be had, and sailed over all the oceans. Everywhere she went, the true north and the magnetic north were recorded. In this way the facts necessary for the making of magnetic maps of the ocean were determined.

417. Swinging ship. A magnet and a piece of soft iron really act as if they were connected by a stretched rubber band. That is, the iron acts on the magnet, just as the magnet acts on the iron.

Now you will see how a ship loaded with iron rails would act on the ship's compass. The earth's magnetism is feeble, and the iron is so close to the compass that its action is great. This makes the compass useless unless the effect is overcome in some way.

Before such a ship leaves harbor, an expert places small pieces of iron very close to the compass in such positions that the compass error is corrected. This is called "swinging ship" because, in doing it,

it is necessary to swing the ship from side to side to make sure that the correction has been properly made.

The small iron correcting pieces are clamped firmly in position. There have been cases where captains have wrecked their ships for the sake of the insurance. This has been done by removing one of these correcting pieces of iron, thus making the compass read incorrectly.

Why does the compass point north and south?
Why does the compass not point true north?
If the compass does not point true north, how can sailors use it?
Where is the north magnetic pole?
Where is the south magnetic pole?
How does a cargo of iron affect the compass?
When a ship is carrying a cargo of iron, how is the compass corrected?

Experiment 67

Question: What is the main law of magnets?

Materials: Bar magnet; suspended compass needle.

Directions: (*a*) Place a bar magnet in a sling and suspend this on a stand. (See Fig. 172.) Place a bar magnet near the suspended magnet so that the N pole of the magnet is near to the N pole of the suspended magnet. 1. What does the suspended magnet do? Bring the S pole of the bar magnet to the N pole of the suspended magnet. 2. What does the suspended magnet do?

Diagram: Show the apparatus in use (Fig. 172).

Conclusion: State the law of the magnet. (Text, Sec. **411.**)

Practical application: It is on this law that the construction of modern dynamos and motors is based.

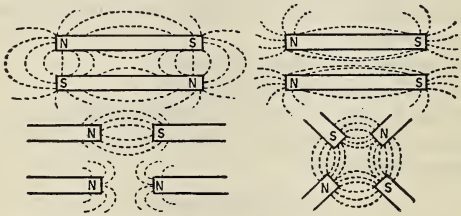
Experiment 68

Question: How can I prove that a field of magnetic force exists around a magnet, and how can I make a map of a field of magnetic force?

Materials: Four bar magnets; a bottle of fine iron filings; cheesecloth and rubber band; sheets of unruled paper.

Directions: (*a*) Half fill a small, wide-mouthed bottle with fine iron filings. Stretch over the top a piece of cheesecloth, and hold this in place with a rubber band. This makes a convenient shaker.

(*b*) Place a magnet on the table and cover it with a sheet of paper. Sprinkle iron filings on the paper until it is well and



Experiment 68

evenly covered. Hold one corner of the paper so that it cannot slide and then tap the paper with your finger or a pencil. 1. Why do the iron filings arrange themselves in lines? 2. Trace these lines until you know just how they go.

(*c*) Place two magnets on the table, side by side, with the N and S poles opposite each other. Cover with a paper, sprinkle on iron filings, tap, and again note how the lines of iron filings arrange themselves. Try the other arrangements shown in the diagram.

Diagram: Show how the filings arrange themselves in the different experiments which you try.

Conclusion: 1. Answer the question. 2. Arrange four magnets in an irregular position. Think over what you have learned about magnetic fields of force, and then sketch roughly what you think will be true about the fields around the magnets. Using iron filings, see whether your prediction was correct.

Practical application: It is this fact, that magnets have a field of force around them, that makes possible motors, dynamos, and our modern electrical science.

NOTE: A simple way to make diagrams of fields of magnetic force, which may be kept in your notebook, is to photograph them. This does not require a camera. Buy a roll of blue-print paper for the class. This is a cheap paper which is coated with a solution that is soluble in water. On exposure to light, this soluble coating becomes insoluble and turns to a dark blue. Engineers use large quantities of such paper in making "blue prints." Of course the paper must be kept in the dark until one is ready to use it.

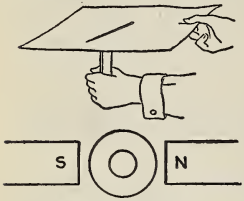
Cut from the blue-print paper a piece conforming in size to the finished picture which you desire. Put the paper over a magnet, scatter iron filings on it, and tap until you obtain a satisfactory field. Then expose the paper to sunlight until the lemon-yellow color changes to gray-blue. Remove the paper, shake off the filings, and place the paper in a dish of water. Where the filings have protected the paper from the action of light, it will remain white. The rest of the paper will be bright blue. Wash the paper well and hang it up to dry. The blue print is permanent. If you have not exposed the paper long enough, the color will be pale. You can afford to experiment with this paper, for it is very cheap.

EXPERIMENT 69

Question: Are all substances transparent to the magnetic force?

Materials: Two bar magnets; sheet of glass; sheet of iron; needle; large iron washers with hole in the center; iron filings.

Directions: (*a*) Place a needle on a sheet of paper. Holding the paper in your hand, place a bar magnet underneath it. Move the magnet around. What evidence have you that magnetic force can pass through paper?



Experiment 69

(*b*) Repeat (*a*), placing the needle on a sheet of glass. Is glass transparent to the magnetic force?

(*c*) Place the two bar magnets on the table, end to end, with the N and S poles opposite each other. Place between the two poles enough iron washers to form a pile as thick as the magnets. (See diagram.) Place a sheet of paper over the magnets, sprinkle iron filings on the paper, and tap the paper. What evidence have you that lines of force prefer to go through iron rather than through air?

(*d*) Place the needle on the sheet of iron. Place the bar magnet under the sheet and move it around as you did in (*a*). 1. Explain what happens to the needle. 2. Is iron transparent to the magnetic force?

Diagram: Draw diagrams that will illustrate what you have done.

Conclusion: 1. Answer the question. 2. Why do men who are working around dynamos (electrical generators) sometimes carry their watches in iron cases?

Practical applications: The knowledge that lines of force prefer to pass through iron rather than air is helpful in building electrical instruments.

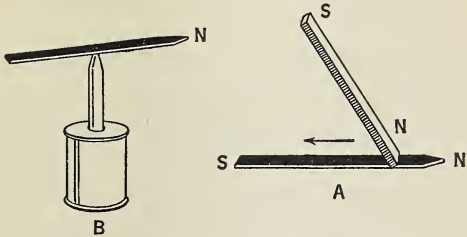
Experiment 70

Question: How can I make a compass?

Materials: A piece of clock spring; an upright support; a bar magnet.

Directions: (*a*) Obtain from your jeweler a broken clock spring. Heat this red-hot and then allow it to cool. This will

take the temper out of the spring, so that you can straighten it. Cut a piece about six inches long and punch a small dent in the center. Push a knitting needle into a wood base. Balance the piece of clock spring on the needle. If necessary, cut a little off one end to make it balance. (See diagram.)



Experiment 70

(*b*) Heat the clock spring red-hot and plunge it into cold water. This sudden cooling will restore the temper (hardness). Stroke the clock spring with the bar magnet, always starting at one end and going to the other end. This will make the spring a magnet. How can you prove that you have made the spring into a magnet?

(*c*) Put your spring magnet on the support. If necessary, cut off a little to make it balance. Give it a spin and notice where it points when it comes to rest. Spin it again and notice that it again comes to rest pointing in the same direction. Why does the spring magnet always come to rest pointing in the same direction? What is this direction?

(*d*) Mark the end of the magnet that points north.

Diagram: Show your finished compass.

Conclusion: Answer the question.

Practical application: We all know the uses of the compass.

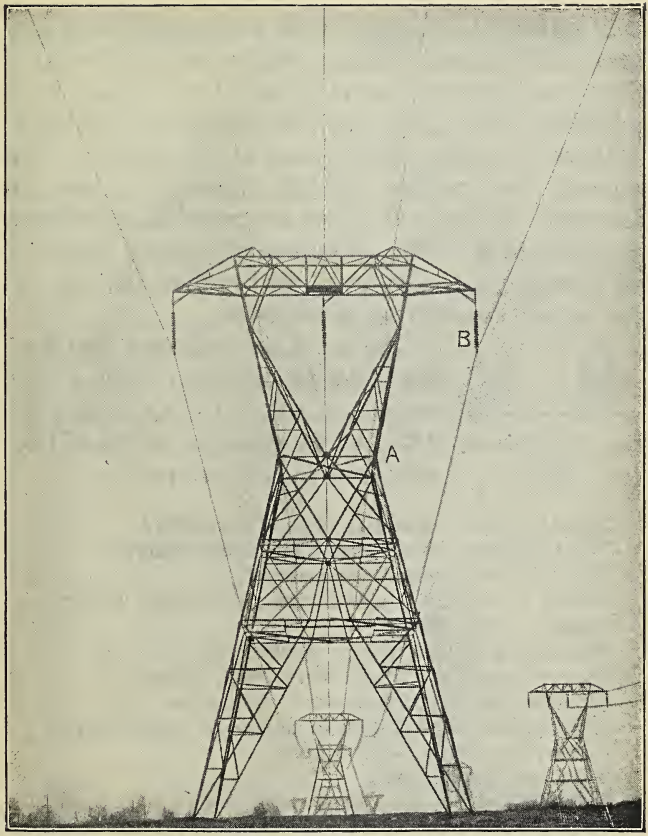
CHAPTER FORTY-SEVEN

SOURCES OF ELECTRICITY

418. Electricity has many uses. One of the ways in which science is making people's lives easier and more enjoyable is by teaching them the many possibilities of electricity. The farmer learns the market price of his crops through the radio. To bring these crops to town he uses a truck, the operation of which depends on electrical ignition. His house is lighted by electric lamps. He milks his cows by electricity. The city man uses the subway or trolley, both operated by electric motors. His morning coffee is made in an electric percolator. His telephone, used so constantly, depends on an electric current. At every point electricity touches his daily life and makes it more pleasant.

419. Some electrical terms. Before we start our study of electricity, there are a few terms that we should understand. A flow of electricity through a wire or other material is called a *current of electricity*, or often simply a *current*.

Materials through which electricity can easily pass are called *conductors*. Metals are good conductors; copper and silver are the best. Aluminum and iron both conduct the current, but not so well as copper.



Courtesy Philadelphia Electric Co.

Fig. 179. Towers carrying a 220,000-volt line. A, the steel supporting tower; B, heavy porcelain insulators

A substance through which the current does *not* pass readily is called an *insulator* or *nonconductor*. Glass and porcelain are nonconductors. Look at a telephone line. It is made of copper wire because that conducts the current used in telephoning. To prevent the current leaking, where the wire is fastened to supports, glass or porcelain *insulators* are used (Fig. 179). Examine the spark plugs of an automobile and you will see another example of the use of porcelain as an insulator.

Fig. 180. Binding posts

The small screw clamps that fasten wires to bells and other appliances are called *binding posts* (Fig. 180). Other electrical terms will be explained as they are used.

What use does the farmer make of electricity?
What use does the city man make of electricity?
What use do you make of electricity?
Where is electricity used in the automobile? in your house? in your school?
What is meant by a current of electricity?
What is meant by a conductor? Name three.
What is meant by an insulator? Name two.
Why are the wires leading to an electric lamp made of copper, but covered with rubber?
What are binding posts?

420. Sources of electricity. There are two common sources of electricity, *dynamos* and *batteries*. The dynamo we shall study later; just now we shall consider batteries.

421. Batteries. Since electricity can do work, it must be a form of energy; and to obtain this energy we must transform some other kind of energy into electrical energy. One simple way to cause an electric current to flow is to transform *chemical energy* into *electrical energy*. This we can do by using a battery.

There are many different kinds of batteries in use, but we shall study only one, the *Leclanche* or *sal ammoniac battery*. The materials in this battery are zinc, carbon, water, and sal ammoniac. The chemical name of sal ammoniac is *ammonium chloride*. The material that furnishes energy is the metal *zinc*. The metal is consumed in the battery. The chemical that enables the energy to be transformed from chemical energy to electrical energy is the sal ammoniac solution. The last part of the battery is a plate of *carbon*.

The parts of the battery are arranged as shown in Figure 181. A is a zinc rod, B a carbon cylinder, and C a solution of sal ammoniac. The chemical energy, which is changed to electrical energy, comes from the solution of the zinc, so the *electricity must*

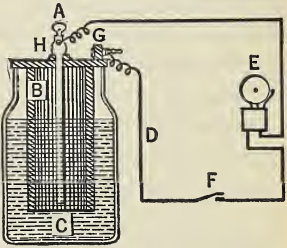


Fig. 181. Sal ammoniac battery. A, zinc rod; B, carbon cylinder; C, solution of sal ammoniac; D, wire leading to switch F; E, doorbell. By pushing down F, the circuit is closed and the bell rings

start at this point. We call the zinc the *positive plate,* because we always speak of electricity as starting at a positive source and flowing from positive to negative. The electricity then flows through the solution to the carbon cylinder. The carbon cylinder is known as the *negative plate.*

The current then goes to the top of the carbon cylinder, from which point it passes off through the wire D, to ring a bell E, or to do other useful work. After going through the bell, it returns by a wire to the top of the zinc rod. We call this complete path of the current the *circuit.* Usually there is a device somewhere in the circuit that stops or starts the flow of the current. This device is called a *switch.* There is one at F.

Inside the battery, then, the current flow is from the positive rod of zinc to the negative cylinder of carbon. *Outside* the battery, the flow is from the top of the carbon cylinder to the top of the zinc rod. We call G, the top of the carbon cylinder, the *positive pole.* We call H, the top of the zinc rod, the *negative pole.* It is usual to indicate the direction of current flow by an arrow, the arrow always pointing in the direction in which the current is flowing.

422. Energy from a cell or battery. A battery, often called a *voltaic cell,* is a device for transforming chemical energy into electrical energy. In commercial batteries, zinc is usually the metal used, and the amount of zinc consumed determines the amount of

electrical energy developed, just as the amount of coal burned under a boiler determines the amount of steam produced. *Zinc is the fuel of the voltaic cell.*

Name the two common sources of electricity.
Why do we say that electricity is a form of energy?
Describe the common sal ammoniac battery.
Draw a diagram of a sal ammoniac battery, marking on it positive and negative plates, positive and negative poles. Indicate by arrows the direction of current flow both inside and outside the battery.
What is meant by an electric circuit?
What is an electric switch?
What is consumed in a battery to furnish energy?
What energy transformation goes on in a cell?
In what way does zinc resemble a fuel?

423. Dry batteries are really wet. Such a battery as we have been studying is suitable for use only where the battery can remain in one position, for, if carried around, the liquid inside might spill. By filling this battery with a material such as plaster of paris or starch, which will absorb the liquid so as to make a pasty mass, what is called a *dry cell* is obtained. The "B" battery in a radio and a flash-light battery are dry cells. They are called dry cells, but if they really were dry they would not work. They must be moist inside.

Batteries that have stood for some time before being used, often dry out and become worthless. To prevent the evaporation of the liquid which moistens the paste inside of a battery, the top usually is sealed with pitch. Saw a flash-light battery in

two, and you will see just how it is made (Fig. 182).

A battery that is too dry sometimes can be made to serve in an emergency. Bore two holes through the pitch, and then place the battery in a pail of water. The water will soak into the battery and restore (temporarily) its usefulness.

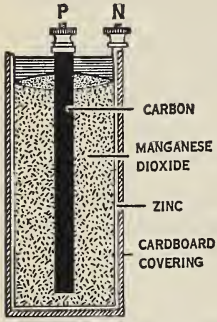


Fig. 182. A dry-cell battery. P is the positive post; N is the negative post

424. Battery uses. Such wet and dry cells are useful only when a small current is needed. They do not last long, but they have the advantage of being cheap and convenient. They are used in flash lights, in radio "B" batteries, to ring bells, to furnish small currents in laboratories, and for similar work. When a stronger current is needed, either storage batteries (Sec. **450**) or dynamos (Sec. **461**) must be used.

425. Open circuit work. Since a Leclanche battery is suited only for intermittent use, it is used for *open circuit work.* An open circuit is incomplete; that is, no current flows over the line. Bell circuits are open circuits. A switch is used to *close the circuit;* that is, to connect the wires so that a current will

Fig. 183. A push button

flow. Push buttons (Fig. 183) are commonly used to close such open circuits.

If you or your small brother build houses of blocks, you can use the knowledge you have gained to wire the house for electricity. Buy at the ten-cent store a one-and-a-half-volt incandescent lamp, a socket, a push button, a dry cell such as is used in flash lights, and some insulated wire. Run wire so as to connect the lamp socket, the push button, and the battery in a circuit. Allow a long enough wire so that the lamp socket can be fastened to the ceiling of the living room, while the push button is placed on the outside of the house where you can reach it. Screw in the lamp, push the button, and the house will be lighted.

It will be interesting, too, to unscrew the end of a flash light, remove the battery, and see why the pressing of the push button on the side of the holder causes the lamp to light. If you have an old dry battery, cut it in half and see how it is constructed.

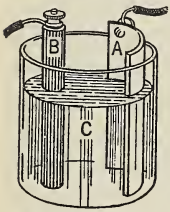
Explain the construction of a dry cell.
Why are dry cells, which have been stored for a long time before they are sold, often found to be useless?
How may such cells be made useful for a short time?
Explain why this method will work.
What are the uses of the cells which we have been studying?
What are the advantages and disadvantages of dry cells?
What is an open circuit?
Explain the construction and use of a push button.

Experiment 71

Question: How can I make a battery?

Materials: Sal ammoniac (ammonium chloride); zinc and carbon plates; battery jar.

Directions: (*a*) Prepare a solution of sal ammoniac. The exact strength is of no consequence, about four ounces to a quart of water being satisfactory. Place the solution in a battery jar. Place in the same jar a stick of carbon and a sheet of zinc. Both of these should have a binding post (see text, Sec. **419**) on the top so as to make it easy to fasten wires to them. If you have no such pieces, you may fasten wires to the zinc and carbon by wrapping wire tightly around them.



Experiment 71

(*b*) Connect a wire leading from the zinc pole to the carbon pole. A current will flow through this wire. To make this evident, hold the wire close to and parallel with a sensitive compass needle. The needle of the compass will deflect, showing the presence of a current.

(*c*) Such a battery may be used only for a short time, because a defect called *polarization* sets in. For this reason do not connect the plates any longer than is necessary to make a test.

Diagram: Show the battery, marking all of the parts. (See text, Sec. **421**.)

Conclusion: Answer the question.

Practical application: Such a wet battery as this was the origin of the ordinary dry cell.

CHAPTER FORTY-EIGHT

ELECTRICAL UNITS

426. What makes electricity flow? What makes an electric current flow? We shall understand this better if we think of the flow of water through a pipe. A reservoir is fifty feet higher than a faucet. Water will gush out of the faucet with a certain force. If the reservoir is one hundred feet higher than the faucet, the water will gush out with twice the force.

The flow of water depends on the *head of water*, or the *water pressure*. The higher the source, the greater the pressure and the greater the ability of the water to push its way through the pipe. In the same way, the greater the electrical pressure, the greater the ability of the current to flow through a wire.

427. The volt. The electrical term corresponding to water pressure is *electromotive force*, commonly abbreviated to *E.M.F.* Just as we call the unit of weight a pound, we call the unit of E.M.F. the *volt*. The higher the *voltage*, the easier it is for the electricity to overcome obstacles, and the greater the force with which it flows.

428. High and low voltages. A sal ammoniac cell gives a voltage of only 1.5 volts; that is, it has

only a small ability to force electricity through a wire. Ordinary house current has a voltage of 110; that is, it can force an electric current to flow where a dry cell would fail. A flash of lightning may have a voltage (E.M.F.) amounting to millions of volts. Lightning, then, can force its way through the air where the house current cannot go.

Touch the two poles of a battery. You feel nothing, for the E.M.F. of the battery is not high enough to force much of a current through the body. If, however, you should touch the two wires of a house current, you will receive a dangerous shock. The E.M.F. of the house current is high enough to force a current through the body.

429. What opposes an electric current? All bodies oppose to some extent the flow of electricity. The better conductor a body is, the easier it is for the current to flow through it. This opposition to the passage of the current is called *resistance*. The unit of resistance is called an *ohm*. Copper has a low resistance, for electricity can flow easily through a copper wire. Iron has a higher resistance than copper, for iron offers more resistance to the flow of electricity than does copper. Rubber has a high resistance, and for that reason it is used to cover wires and thus prevent the escape of electricity from them.

430. The ampere. We cannot see electricity, nor can we weigh it, but we have ways of determining the rate at which it flows through a wire.

The unit rate of current flow is named an *ampere*. Just as we might speak of a water flow of eight gallons per minute, we speak of an electrical flow or current of twelve amperes.

431. Ohm's law. These three units, *volt* (pressure causing electricity to flow), *ohm* (resistance to flow), and *ampere* (rate of flow), were named for three great scientists, Volta, Ohm, and Ampere. The three measurements that they represent are dependent on one another. If we increase the resistance (ohms), a smaller current (amperes) will flow. If we increase the electromotive force (volts), a larger current (amperes) will flow. It is useful to know what the relation between these three units is, so we give it below in the form that is called *Ohm's Law*.

$$C \text{ (amperes)} = \frac{E \text{ (volts)}}{R \text{ (ohms)}}$$

432. Electric power. Since the production of electric current requires the outlay of money, and since this current is sold for so many different uses, it is necessary to have some convenient method of naming the amount of electric power that lamps, motors, or radios use.

433. Watts. The unit of electric power, or the rate at which electricity will do work, is the *watt*. We can determine the watts by multiplying together the volts and the amperes. The watt is a very small unit. For practical purposes, electric companies

use a meter which measures watts by the thousand, called *kilowatts*. When you have used one kilowatt for one hour, you have used up one kilowatt hour of electrical energy, and this is the unit used by electrical companies in making out their bills to the users of electricity.

434. Our electric bill. Many electrical appliances are stamped with the watts required to operate them. If an electric iron is marked "660 watts, 110–120 volts," you know that it is designed to work on your house current, for that current gives you 110 volts. If you use it for one hour, it will use up 660 watt hours, or 0.66 kilowatt hour of electricity. If current costs 10 cents a kilowatt hour, it will cost 6.6 cents to use the iron for one hour.

435. Cost of an electrical appliance. When you buy an electrical appliance, do not be satisfied with a vague statement that it requires only a trifle to run it. Instead, find out the watts that it uses, and then you can find out for yourself whether it will pay you to buy it. An electric toaster may require 660 watts (0.66 kilowatt). At 10 cents a kilowatt hour it will cost 6.6 cents an hour to use it. If it is used 30 hours a month, the monthly cost will be about $1.98.

The next time that the man comes to read your electric meter, ask him to explain to you how it operates. You will find that the "wattmeter," as the electric meter is called, is really a small motor through which passes a small part of the current which you use.

The shaft of the motor is connected by gears to a set of dials, and by reading the position of the hands on these dials, the amount of current you have used is determined. If a mistake has been made and if the employee of the electric company has read the dials so as to make your bill too large this month, you need not worry about it, for the reading next month will be less than the amount registered, so that the total amount you pay will in the end be correct. Can you think why this is true?

What does E.M.F. stand for?

What is the unit of electrical pressure? of electrical resistance? of electrical flow?

Why can we touch the poles of a battery safely, while if we touch the wires of a house current, it is dangerous?

State Ohm's law.

How can we find the number of watts used in a lamp?

How can we change watts to kilowatts?

Read the label on some electrical appliance and calculate what it costs to run it for one month.

A motor operates on 200 volts and three amperes. The charge is five cents a kilowatt hour. It is used 200 hours during the month. What should be the amount of the bill?

A boy uses a toy motor for ten hours. He operates it from a storage battery giving six volts, and the current required is one ampere. How many watt hours has he used?

A motor takes 36,000 watts. At three cents a kilowatt hour, what does it cost for each hour that it is used?

Which will cost more, to operate a lamp marked forty watts or a lamp marked eighty watts?

A six-volt storage battery is giving eight amperes. How many watts are being used?

CHAPTER FORTY-NINE

HEATING EFFECTS OF THE CURRENT

436. Resistance causes heat. Imagine yourself walking through a pipe six feet in diameter. You can walk as easily as you do out of doors. Imagine, though, that you had to get through a pipe one foot in diameter. You will find it difficult, for you will need to wriggle through, flat on your stomach, and, by the time you get through, you will feel warm. The small pipe will offer more resistance to your passage.

Exactly the same thing is true of the electric current. It passes easily through a large wire, but when it is forced through a small wire, *much heat is developed.* The resistance of the small wire is greater than that of the large wire. Often this is a disadvantage, for it wastes the current. It is possible though to make use of this heat to do useful work.

437. House wiring. Suppose that you are wiring your house for electricity. You will first estimate the largest amount of current that you are likely to use at any one time. If you think that on a certain night you may be burning 20 lamps, each requiring 40 watts, and that at the same time you might be using an electric grill that would require

660 watts, you would be using in all 1460 watts. If your house current is 110 volts, this means that you would be using 13 amperes of current. In wiring your house, then, you must use a wire that will carry 13 amperes safely, without too much heating. If you use a smaller wire, it may become so hot that it will char the woodwork and finally cause a fire.

What determines the heat produced in an electric circuit?
Small wire is cheaper than large wire. Why is small wire not used in wiring houses?

438. Safety fuses. Many of us do not know what size of wire was used in wiring the house we live in, nor do we know what the safe carrying capacity of the wire is. It is therefore necessary for safety's sake to have some device to prevent using a dangerously large current. This safety device is called a *fuse.*

To prevent the dangers that too large currents may cause, fuses are always placed in every electrical circuit. These fuses are short pieces of wire, made of a metal, mainly lead, that melts at a low temperature. By varying the size of the fuse wire, we can cause it to melt when any specified current passes through it. Fuses are inclosed in an outside case to prevent the molten metal from escaping (Fig. 184).

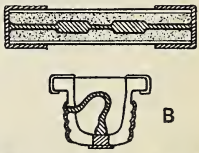


Fig. 184. A, cartridge fuse; B, plug fuse in section

Perhaps you have been reading and all the lights have gone out. Your father has said, "The fuse has blown. I must put in a new one." He goes to the *fuse box*, unscrews the old fuse, and puts in a new one.

439. Fuse capacity. The safe carrying capacity of a fuse is marked on it. When a fuse blows, or melts, one is apt to look at the number and think, "A six-ampere fuse blew, I will put in a twenty-ampere fuse, and that certainly will not blow." *Do not do this.* If a room is so wired that it will carry six amperes safely, and if a six-ampere fuse is put in the circuit, and this fuse blows, it is a sign that the circuit is being overloaded. Find out the trouble, but do not use a larger fuse. Crossed wires cause a very large current to flow. In one case, a house owner, finding that even a large fuse blew, put in a penny instead of a fuse. His house burned because the wire became hot enough to set fire to the woodwork and the penny gave no hint of the overload.

Of what is a fuse composed?
Why is it used?
Why is it called a safety device?
Why should a small fuse *not* be replaced by a large one?
Fuses cost money; why use them?
How may the current that a fuse can safely carry be determined?

440. One electrical danger. From time to time a householder may buy additional electrical appliances and use them without thought of the possible

danger they may cause. If a dining room has been wired to carry safely lamps using 660 watts, one cannot add a toaster, a grill, and a percolator, *each* of which requires 660 watts in its operation, without dangerously overloading the circuit.

The larger the current of electricity, the greater the heat, but this heating effect varies as the square of the current. That is, if we make the current three times as great, we get not three times as much heat but nine times as much. In the case of the dining-room wiring, the lamps alone would use 660 watts. The lamps plus the toaster and the other appliances would use 2640 watts. This large amount of heat, which has been increased sixteen times, quite possibly would be enough to cause a fire.

If the current flowing in a wire is doubled, what effect has this on the heat produced?

A factory using five motors, all alike, installed ten more similar motors. A fire developed. What was one probable cause?

What is one indication of an overloaded circuit?

441. Incandescent lamps. Why do you suppose the Romans went to bed early, and why were the streets of Paris almost deserted after sunset during the Middle Ages? It was because of the lack of light. The Romans had lamps, it is true, but one of their small smoky lamps would not give so much light as one of our

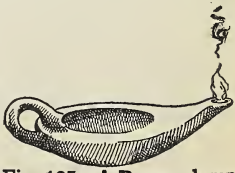


Fig. 185. A Roman lamp

modern candles (Fig. 185). In the same way, the streets of Paris were lighted by only a few lamps which were hung in the principal streets.

Science has given us our modern lamps. Whether we live in the cities and use electric lights, or whether we live in a lonely ranch house and have to rely on gasoline or kerosene lamps, our illumination is better than that in any king's palace of years ago. Imagine trying to study, as Abraham Lincoln did, by the flickering light of a wood fire.

442. Tungsten. We have learned that when a current passes through a small wire, the wire becomes hot. If the wire be small enough and the voltage high enough, the wire will be heated so hot that it will glow. This is the principle of the electric lamp. A wire, usually of a metal called *tungsten*, is drawn out until it is as fine as a hair. This very fine wire is mounted inside a glass globe and the air is pumped out of the globe. Wires also are provided to lead the current into and out of the lamp (Fig. 186). When the current passes through the fine tungsten wire, the wire becomes white-hot, and we have an incandescent lamp.

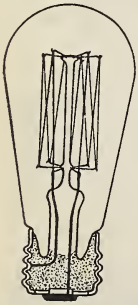
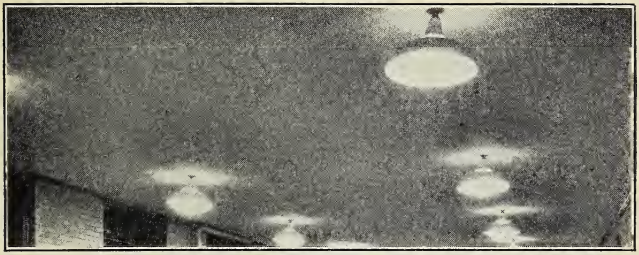


Fig. 186. An incandescent lamp

443. Gas-filled lamps. Formerly the air was exhausted or taken out from all such lamps. This was necessary to prevent the oxidation of the white-hot



Direct lighting

Indirect lighting

Semidirect lighting

Fig. 187. Three examples of lighting

metal. Now lamps are filled with a gas, such as nitrogen or argon, that will not act on the tungsten. These *gas-filled* lamps give a brighter light than the ordinary lamps because it is possible to heat the tungsten wire hotter.

444. House lighting. An incandescent lamp is so bright that its unshielded use may cause eyestrain. One common way of diffusing or scattering the light is to etch the inside of the globe so that it resembles ground glass. Another method is to use an opal or ground-glass globe between the lamp and the eyes. Figure 187 shows several methods of lighting.

445. Direct and indirect lighting. If the light rays from an unshielded lamp pass directly down on a book, that is known as *direct lighting*. For the general lighting of a room, this is the poorest method. If a translucent shade is placed between the reader and the lamp, the room is lighted by *semidirect lighting*. If a shade is put under the lamp so that much of the light is reflected upward and gives a soft, even glow, it is known as *indirect lighting*.

What is the principle of the incandescent lamp?
What metal is used generally in such lamps?
What are gas-filled lamps? Why are they used?
Distinguish between direct, semidirect, and indirect lighting.

446. Heating by electricity. The principle used in all electrical heating devices is the same. A cur-

rent passes through a wire of high resistance, the wire becomes hot, and this heat may be used to warm a trolley car, toast bread, and heat flatirons.

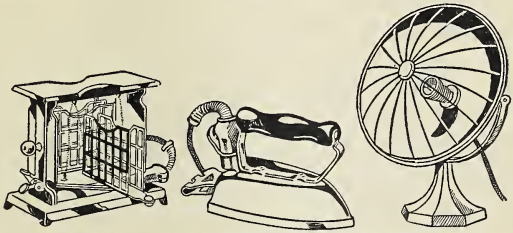


Fig. 188. Some electrical heating devices

An electric toaster, flatiron, and heater are shown in Figure 188. In the center of the heater you will see a coil of wire. This is the heating element. It is a coil of *nichrome wire,* which has a high resistance and does not easily oxidize. When a current is sent through it, it becomes red-hot and the reflector behind it reflects the produced heat into the room. The flatiron and the toaster are similar in construction. In the flatiron the heating element is in the body of the iron and you cannot see it, but in the toaster it is in plain sight. The next time that you use your toaster, look into it and you will see the glowing wire.

Explain the principle of an electric flatiron.

An electric stove has two heats, a high and a low. How is this possible?

What may be wrong if an electric toaster refuses to heat?

CHAPTER FIFTY

CHEMICAL EFFECTS OF CURRENTS

447. Silver plating. Plated silver costs less than solid silver and for many purposes is just as satisfactory. But do you know how this electroplating is done? Arrange the apparatus as shown in Figure 189. Prepare a solution of copper sulphate. Pass a current through this solution. You will see that the plate through which the current *leaves* the solution becomes covered (plated) with copper. The current has broken up or decomposed the copper sulphate and transferred copper from the plate where the current *enters* to the plate where the current *leaves*.

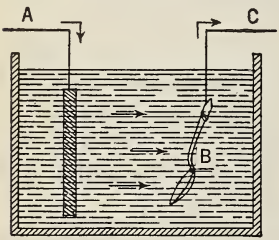


Fig. 189. The current enters at A, is carried by a particle of copper through the solution to the spoon B, where the copper is deposited. The current then leaves at C

If a plate of brass had been hung where the current leaves, it would have been covered with copper. If, instead of using a solution of a copper compound, a solution of silver had been used, the brass would have been silver plated. Gold, nickel, and other metals may be plated in the same way.

448. Metals obtained electrically. Aluminum and some other metals are obtained from their ores by an electrical process. Passing an electric current through dissolved or melted metallic compounds decomposes them; that is, the current breaks them into smaller parts. If oxide of aluminum is dissolved in a solution of the melted mineral, cryolite, and then a current is passed through the molten mass, the aluminum is deposited on the carbon plate that forms the bottom of the box in which the operation is carried out. This aluminum melts because of the heat, and is drawn off from time to time.

The discovery of this process has made cheap aluminum possible. In 1855 the price of aluminum was $600 a pound. It is now about twenty-five cents a pound. Thus the chemists have made it possible for householders to use aluminum pots and pans.

449. Electric furnaces. Often the heat created by the flow of an electric current is used to produce chemical changes. Sand, salt, coke, and sawdust are placed in a large brick box. Two pieces of carbon are placed, one at each end of the box, so that they project into the box. Through these carbon poles a heavy current is passed. So much heat is produced that the mass in the box melts, a chemical change takes place, and a new compound called *carborundum* is made. This is a very hard substance and is used to make grinding wheels and whetstones for sharpening knives and other tools.

Draw a diagram and explain the process of copper-plating an iron spoon.
Explain how to silver plate a copper spoon.
How is aluminum obtained from its ores?
How is carborundum made?
For what is carborundum used?

450. Storage batteries. The *storage battery* that is used in automobiles and radio sets is a battery of very different construction from a dry cell. One plate of the storage battery is of lead and the other of an oxide of lead. The liquid of this battery is sulphuric acid (Fig. 190). It gives a higher voltage than a dry cell, and, for the same sized battery, can give a much larger current. A storage battery is much more expensive to construct than a dry cell. Such a battery would be too expensive to use if it were not for the fact that, after using it until exhausted, the battery may be recharged or restored to its original condition.

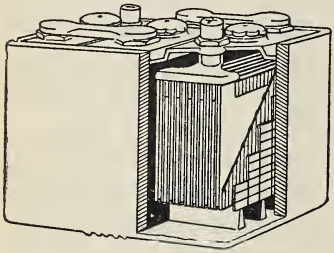


Fig. 190. A storage battery

451. Chemical energy produces a current. The common idea is that a storage battery stores electricity. This is not true; it stores chemical energy. It is an ordinary battery in which chemical changes take place, a current of electricity is produced and

the battery becomes exhausted. If, after the battery is exhausted, a current is sent through the battery in the opposite direction from that in which the current naturally flows, the chemical changes are reversed, and the battery is once more in its original state. This can be repeated many times.

452. Transformation of energy. Some transformations of energy are reversible; some are not. Sound can set a disk in vibration, and a vibrating disk can produce sound. This is an example of a *reversible energy change.* The explosion of gunpowder can force a bullet from a gun, but forcing a bullet into a gun will not explode gunpowder. This is an example of a *nonreversible change.*

In an ordinary dry cell the current uses up the zinc, and this change is practically a nonreversible one. In a storage battery, however, the change is reversible. First, chemical changes in the storage battery give a current. But the chemical solution of the storage battery differs from that in a dry cell. Forcing a current through it in the opposite direction reverses this chemical change and renews the storage battery.

What materials are used in the storage battery?
A storage battery costs many times more than a dry cell. Why can we afford to use one, nevertheless?
Name one reversible and one nonreversible energy transformation.
Name some uses of storage batteries.

CHAPTER FIFTY-ONE

MAGNETIC EFFECTS OF CURRENT

453. Magnetic field around a wire. Send a current through a wire, and then hold the wire over a compass (Fig. 191). The compass needle will swing to one side, just as if a magnet had been placed over it. Place the wire carrying the current under the needle and you will see that once more the needle swings to one side, but this time the swing is in a direction opposite from its swing when the wire was above the needle. If the direction in which the current is flowing is changed, the direction in which the needle swings is changed. The needle acts as if a magnet had been placed over it and the direction of the north and south poles had been reversed.

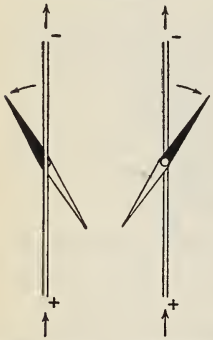


Fig. 191. Magnetic field around a wire carrying a current

These experiments prove that *a current creates a magnetic field around the wire which carries it.* This fact is valuable in constructing dynamos, motors, telephones, telegraph instruments, bells, and many other electrical instruments.

Describe what takes place in the space around a wire carrying an electric current.

454. Electromagnets. Wind ten turns of wire around a bar of soft iron (Fig. 192) and dip the end of the iron into a heap of iron filings. The iron bar is not a magnet and does not pick them up. If a current is passed through the wire and the end of the iron bar is then dipped into the filings, it will pick them up. Or, *if a current is passed through a coil of wire wound around a soft iron bar, it will be changed into a magnet.* Stop the current and the filings fall off. This is only a temporary magnet. Such magnets are called *electromagnets.*

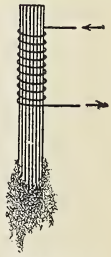


Fig. 192 One form of electromagnet

455. How to make strong electromagnets. Wind twenty turns of wire around the same bar. The bar will then pick up twice as many filings as it did with only ten turns. The *strength of an electromagnet increases as the number of turns of wire are increased.*

Repeat the experiment, using the current from only one dry cell. Only a few filings are picked up. Use the current from two dry cells and about twice as many filings will be picked up.

The strength of an electromagnet, then, can be increased in two ways: by increasing the number of turns of wire wound around the iron bar, or *core,* as it is called; and by increasing the current that flows through the wire.

456. Which is the north pole? Again pass a current through the coil and determine which end of the core is the north pole. This you learned how to do in the chapter on magnetism. Change the direction in which the current is flowing and again determine which end of the iron core is the north pole. You will find that the poles have exchanged places. The direction in which the current flows around the core determines which end of the core is the north pole.

457. The magnetic field. That there really is a magnetic field around the wire is shown not only by the experiments that have just been described, but also by the use of iron filings, if the current is strong.

Put the wire through a hole in the center of a piece of cardboard, sprinkle iron filings on the card, and then pass a heavy current through the wire (Fig. 193). Tap the card, and the filings will arrange themselves in circles, showing that there is a magnetic field around the wire (Sec. **413**).

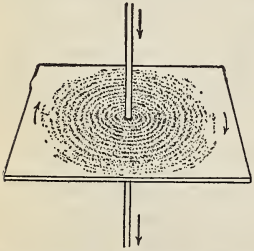


Fig. 193. Magnetic field around wire as shown by iron filings

458. A summary to help you. Summarize then, these facts which you have learned. If a wire is wound around a bar of soft iron and a current is passed through the wire,

the bar becomes a temporary magnet. Such a magnet is called an *electromagnet*. Increasing the current strength or increasing the number of turns of wire, makes the magnet stronger. Changing the direction in which the current flows makes the north and south poles exchange places.

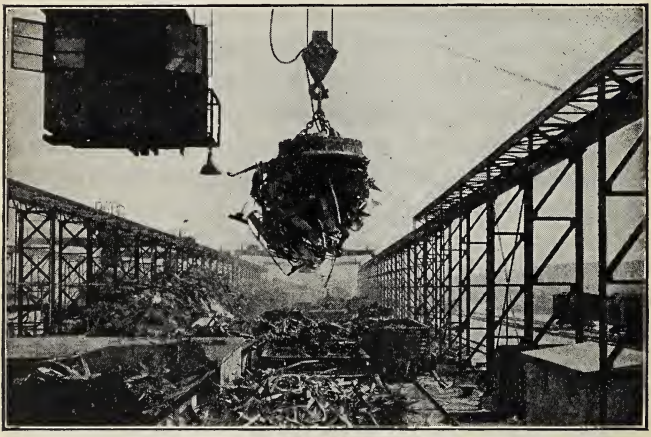
Such magnets are only temporary. They may be made very strong. They are very important, for they are used in many kinds of electrical work. This principle, that a wire carrying a current has a magnetic field around it, makes it possible to make use of motors and dynamos.

In what two ways can the strength of an electromagnet be increased?
How can you prove that a wire carrying a current has a magnetic field around it?
How can you make the north pole of an electromagnet the south pole?

459. Uses of electromagnets. Later we shall study many interesting uses of electromagnets, but we shall mention a few here. In iron works there is an immense amount of scrap iron to handle. Such work is hard and disagreeable. Instead of carrying the scrap by hand, a large electromagnet is used. The electromagnet is swung over the heap of scrap, the current turned on, and the magnet picks up perhaps a ton of scrap iron. The magnet, which is hung from an electric crane, is then swung over the place where the scrap is wanted, and the current

is turned off. The magnet ceases to be a magnet, and the scrap iron drops (Fig. 194).

Electromagnets also may be used in breaking up masses of iron. A huge ball of iron is picked up

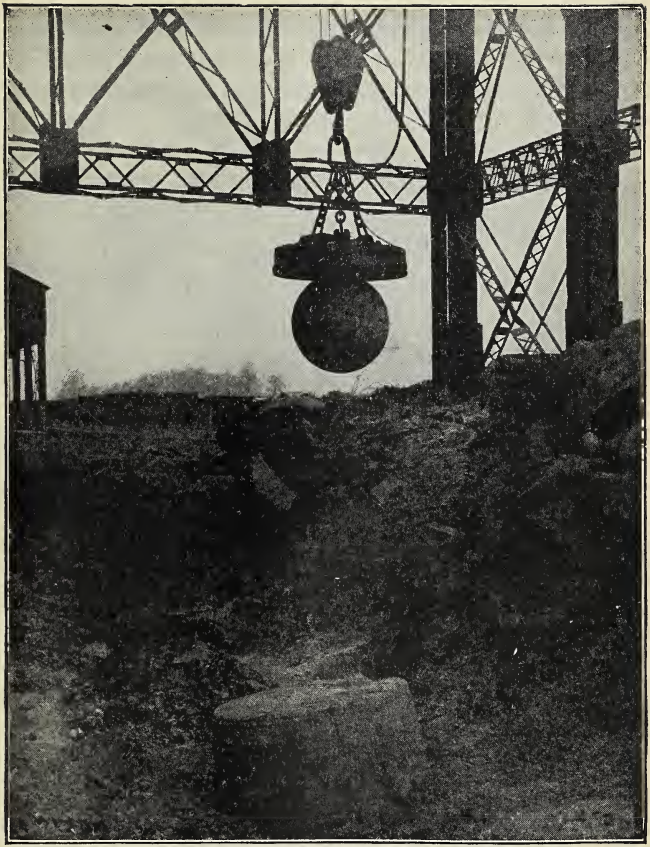


Courtesy Ohio Manufacturing Co

Fig. 194. A huge electromagnet lifting scrap iron. The movements of the magnet are controlled by the operator in the cage at the upper left-hand corner

by an electromagnet, raised high in the air, and then dropped, by cutting off the current. The iron ball in falling, drops on the iron and breaks it up (Fig. 195).

One town in the West has used electromagnets to clean up its roads. The roads were full of nails, which caused many automobile tire punctures. By



Courtesy Ohio Manufacturing Co.

Fig. 195. An electromagnet lifting a ten-ton iron ball. The fall of the ball is used to break up masses of iron

using a row of electromagnets, fastened in a line, near to the surface of the road, the nails attached themselves to the magnets and the road was cleaned (Fig. 196). The North Dakota Highway Depart-

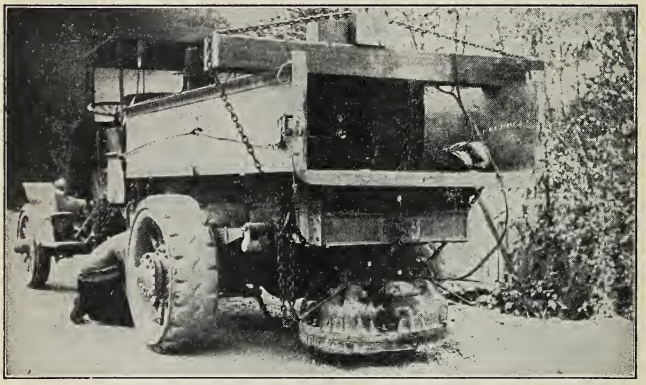


Fig. 196. This is an electromagnet used as a means of sweeping the street free of iron nails, tacks, etc.

ment *Bulletin*, No. 7, describes the work of a magnet used to clean roads in that state:

The magnet picks up an average of about 12 pounds of iron and steel for each mile of road. Of this amount, one pound was found to contain 102 large nails, 187 small nails, 30 tacks, 8 brads, 1 needle, 2 screws, 38 pieces of wire, and 1 razor blade. A tire repair shop reports that punctures dropped 40 to 50 per cent after the trucks had cleaned up the road.

Mechanics often get small pieces of iron in their eyes. Sometimes these pieces are difficult to remove. An electromagnet with a long, pointed end solves the problem. The pointed end is brought near the eye. The result is that the iron jumps out of the eye and sticks to the magnet. An ordinary magnet could not be made strong enough for this use.

How may an electromagnet be used to move scrap iron?
Explain how an electromagnet is used to break up large masses of iron.
Give a good plan for separating a mixture of brass and iron filings.
How are iron filings removed from a road? from an eye?

460. Why dynamos are necessary. We can afford to burn zinc in a battery when we need only a small amount of electricity, but if we had to rely entirely on batteries for electricity, the modern use of the current would be impossible. The current which is used in electric lamps and appliances would cost too much. When we need large quantities of electricity, we use *generators* or *dynamos* which transform mechanical energy into electrical energy.

461. The principle of the dynamo. It has been found that when a wire is moved between two magnets in such a way that it cuts across the lines of force, an electric

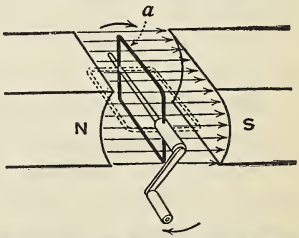


Fig. 197. The principle of the dynamo

current is generated in the wire (Fig. 197). It is only necessary then to find a cheap, easy way of keeping a wire moving between the poles of a magnet to have a dynamo, or a machine that will transform mechanical energy into electrical energy.

A device for doing this is shown in Figure 198. A loop of wire *a* is mounted so that it may be rotated between the magnet poles N.S. A current is produced in the loop. This current passes to the external circuit through the two pieces of carbon *b*, *b′*, called *brushes*. The current produced in such a dynamo is *alternating*. That is, it flows in one direction and then in the other. By a special device called a *commutator*, it is possible to change this alternating current into a *direct current;* that is, a current that flows always in one direction, such as is given by a battery. For most purposes the alternating current, or *a.c.* as it is often abbreviated, is satisfactory. For a few uses, such as electroplating, it must be changed into direct current, or *d.c.* as it is called.

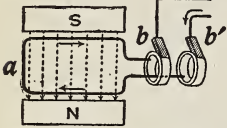
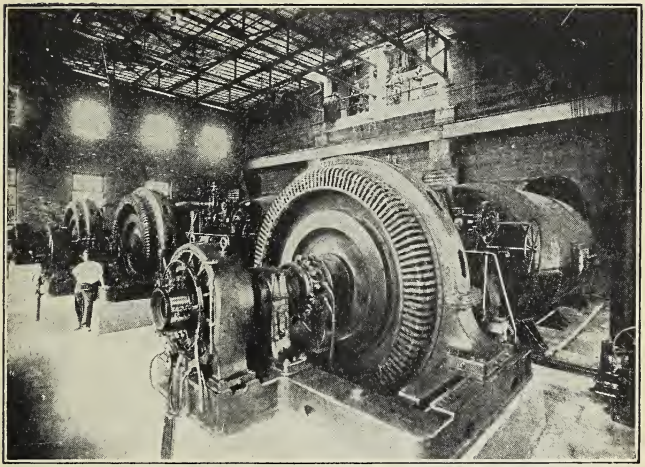


Fig. 198. A simple dynamo

462. Commercial dynamos. Commercial dynamos are quite different from a small model. Instead of using one magnet, several electromagnets are used. Instead of using one loop of wire, many turns of wire, wound on an iron core, are used. This is called an *armature*. These changes all



Courtesy Westinghouse Electric & Mfg. Co.

Fig. 199. This photograph shows three large commercial dynamos

increase the efficiency of the dynamo, but do not change the principle on which it works. Small model dynamos are made in which the loop of wire may be turned by hand. Such a small dynamo will give current enough to light a small lamp.

What is the principle of the dynamo?
What is meant by a.c.? d.c.? Which current is produced by a battery?
How do commercial dynamos differ from the simple, ideal dynamo shown in Figure 198?
What is meant by an armature?

463. Motors. The dynamo is a reversible machine. Turn the armature by power, and you gen-

erate a current. Turn a current into the armature, and the armature will rotate. In the first case, mechanical energy is being changed into electrical energy; a dynamo is produced. In the second case, electrical energy is being changed into mechanical energy; a *motor* is produced. Figure 200 shows how such a motor works.

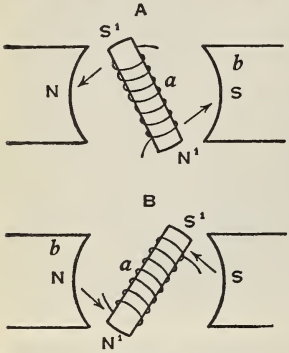


Fig. 200. Principle of the motor

When the armature is in the position shown (Diagram A), and a current is passed through it, it is made an electromagnet, with the poles as marked. You will see that the poles of the armature and magnet are so placed that they attract each other. This will make the armature start to rotate. Now look at Diagram B where the *direction of the current in the armature has been reversed.* You will see that the poles are now so placed that they repel each other, and that this will cause the rotation of the armature to continue. By reversing the current in this way at each half revolution of the armature, the armature will continue to turn. Thus a *motor* is made. The electric fan, the vacuum cleaner, the electric refrigerator, the electric sewing machine, and the trolley car all depend on the use of such motors.

What is the difference between a dynamo and a motor?
How may a motor be changed into a dynamo?
How may a dynamo be changed into a motor?
Explain the use of the electromagnet in a motor.
What is the principle of a motor?

EXPERIMENT 72

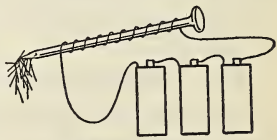
Question: How can I make an electromagnet?

Materials: Dry cells; a large wire nail; a piece of ordinary bell wire; small wire; brads.

Directions: (*a*) Connect three dry cells in series. Your instructor will explain to you what this means and what is its effect on the current. Remember that cells should not be connected on a closed circuit except during the time that you are actually trying an experiment.

(*b*) Wind ten turns of wire around the nail. Connect the wire to the battery and then dip the end of the nail into a heap of small brads. Notice how many the nail, which is now an electromagnet, picks up. Break the circuit. Try again to pick up the brads with the nail. The strength of the magnet is measured roughly by the number of brads it will pick up. Why should passing a current through the wire make the nail a magnet? (Text, Sec. **454**.)

(*c*) Wind twenty turns of wire around the nail. Again pass a current through the wire, and see how many brads the nail will pick up. Break the circuit. 1. What effect does increasing the number of turns of wire have on the magnetic strength of the electromagnet? 2. Why do electromagnets usually have many turns of wire on them, rather than a few?



Experiment 72

Diagram: Show the electromagnet that you made.

Conclusion: Answer the question.

Practical application: Such electromagnets are used in telephones, telegraph keys, electric bells, motors, and generators.

CHAPTER FIFTY-TWO

TELEPHONE, TELEGRAPH AND ELECTRIC BELL

464. The telephone wire and the human voice. Have you ever thought about what happens when you speak into a telephone? The common idea about a telephone is that it transmits sounds over a line. A moment's thought will show one that this is impossible. We telephone from New York to Los Angeles. Everyone knows that it would be impossible to send sound waves such a long distance.

If it is not sound that travels over the telephone wires, what is it? It is a *varying electric current.* If you have understood the chapter on the magnetic effects of the electric current, you will soon understand how the sound waves cause a changing electric current, and how this current is changed back into sound waves.

465. The telephone system. Now let us see just what happens when we speak into a telephone. In its simplest form, a telephone system has only three parts: a transmitter, a receiver, and a wire carrying a small current connecting them. Just behind the mouthpiece that you speak into is the real transmitter, shown in Figure 201. This is a

small box filled with carbon granules or carbon grains. The front and back of the box are made of thin polished plates of carbon. The sides of the box are made of insulators. Attached to the front of the box is a thin metal *diaphragm,* or sheet of thin metal.

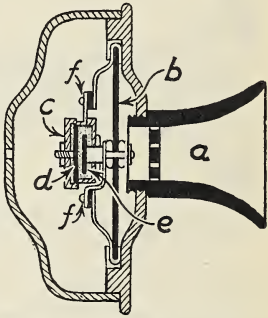


Fig. 201. A telephone transmitter. An electrical circuit exists through the loose carbon granules in a chamber between two plates of gas carbon *d* and *e*; *f*, *f* are the terminals to which the wires completing the circuit are attached. The black markings at *f*, *f* are insulation

466. Vibration of transmitter. When you speak into the transmitter, you set this thin plate in vibration. This vibrating plate, because it is attached to the front carbon plate of the box, sets this plate in vibration, or sets it moving back and forth. This in-and-out motion of the carbon plate squeezes the carbon granules in the box more or less tightly together. When the front of the box moves *in,* the granules are squeezed more tightly together, and their *resistance is decreased,* for the granules are being made more nearly into a solid block. When the front of the box moves *out, the resistance is increased,* for the granules are being made into a loose heap of carbon.

467. Variation of current. A small electric current flows into the front of the transmitter

box, through the carbon granules, out of the back plate, and then passes over the telephone wire to the distant receiver. *Every change in the resistance of the carbon granules will cause this current to vary.* When you speak close to the mouthpiece of the transmitter, you cause sound waves in the air. These sound waves set the transmitter diaphragm in vibration, and this vibration in turn changes the resistance of the carbon box. This operation causes the current flowing over the line to *vary in strength.*

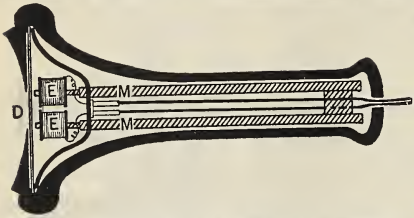


Fig. 202. Receiver of a telephone. M, M, U-shaped magnet; E, E, coils; D, disk

468. The telephone receiver. The telephone receiver is a U-shaped magnet. Around each pole is wound a coil of many turns of fine wire. In front of the poles, but not quite touching them, is a thin disk of iron. This disk is attracted by the magnet, and is prevented from slipping off by the cover of the receiver. The arrangement is shown in Figure 202.

469. Why we can hear through the telephone. If a current in one direction is sent through the coils of wire wound around the poles, the magnetic strength of the poles will be increased (Sec. **455**).

Increasing the current strength will also increase the magnetic effect. If a current is sent in the opposite direction, or, if the current strength is decreased, the magnetic strength of the poles will be decreased. These increases and decreases of the current will cause the thin iron disk to move nearer to, or farther from, the poles of the magnet, or will cause it to vibrate.

We learned that if we speak into the mouthpiece of the transmitter, we alter its resistance, and so cause a varying current to flow over the telephone line. We also learned that a varying current will cause the diaphragm of the telephone receiver to be set in vibration. You will see that the vibrations of the diaphragm of the transmitter will be exactly reproduced by the vibrations of the diaphragm of the telephone receiver. The air in front of the receiver diaphragm will then be set in vibration, or sound waves will be formed, and these sound waves will be just the same as the original sound waves. In this way we hear, not the original sound, but a reproduction of the sound.

470. Telephone systems. This is only an outline of the simplest telephone line. In commercial telephone exchanges, the operation is much more complicated because of the large number of lines. Local lines cover private-home telephones and the more intricate commercial telephones. The lines of local telephones join in a local exchange, which in turn

is connected with main trunk lines going from community to community. All these must be joined in a manner which prohibits electrical interference and limits the cost of operation.

Many telephone companies welcome visitors to their exchanges. If yours does, a class visit will prove both interesting and instructive.

What really happens when you speak into a telephone?
Of what use is a telephone transmitter?
Of what use is a telephone receiver?
How could you make a telephone receiver produce sound, if you had no transmitter?
Why does speaking in front of the transmitter cause a varying current?

471. How savages telegraph. How to communicate quickly with friends who are at a distance has always been a problem. Savages beat drums, the sound of which carries a long distance. The Indians used smoke signals (Fig. 203). By building a fire of green wood, a column of smoke was made to rise in the air. The Indians then threw a wet blanket on and off the fire, causing the fire to break the column of smoke into puffs. By using a system of smoke puffs, signals could be sent. It was not until Samuel Morse, in 1844, discovered the

Fig. 203. The Indians telegraphed by smoke signals

principle of the telegraph, that cheap, satisfactory, long-distance messages could be sent.

472. Principle of the telegraph. We know what an electromagnet is, and that such an electromagnet attracts iron (Fig. 192). When a piece of soft iron R (an *armature*, Fig. 204, Diagram A) is hung close to the poles of a horseshoe electromagnet and a current

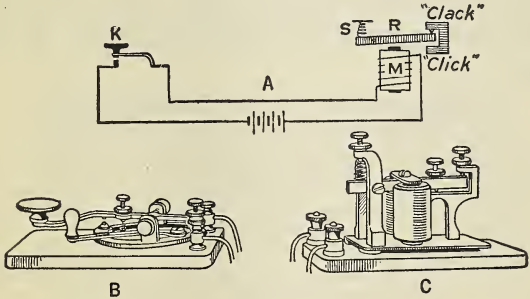


Fig. 204. A, principle of telegraph key and sounder; B, commercial form of telegraph key; C, commercial form of telegraph sounder.

is passed through the magnet, the armature will be pulled to the poles of the magnet, making a *click*. When the current is stopped, the armature is pulled back by the spring S, and strikes the stop, making a different sound that is called a *clack*.

473. Dots and dashes. Closing a switch K (Fig. 204) for an instant only, sends a momentary current through the line, and the *click-clack* pro-

duced will come so close together as to make really only one sound. By closing the switch for a half second, a *click* followed by a *clack* is made after a short time. We shall hear two distinct sounds. This is the principle of the telegraph. A short sound is called a *dot*, and a long sound is called a *dash*. By using the switch, we can make dots and dashes which we can use as signals, much as the Indians used their smoke puffs. The Continental Code, used in sending wireless messages, is given below.

TABLE OF THE CONTINENTAL CODE

A ·—	H ····	O ———	V ···—
B —···	I ··	P ·——·	W ·——
C —·—·	J ·———	Q ——·—	X —··—
D —··	K —·—	R ·—·	Y —·——
E ·	L ·—··	S ···	Z ——··
F ··—·	M ——	T —	
G ——·	N —·	U ··—	

Numerals are given as follows in Morse (I and II)

I. International Morse		II. American Morse	
1 ·—————	6 —····	1 ·————·	6 ·····
2 ··—————	7 ——···	2 ··——··	7 ——···
3 ···——	8 ———··	3 ···——·	8 —····
4 ····—	9 ————·	4 ····—	9 —··—
5 ·····	0 —————	5 ———	0 ——

474. Use of the telegraph. Commercially, for the sake of economy, we use the system shown in Figure 205. We wish to telegraph from Chicago to St. Louis. Only one wire is needed, for the earth will be used instead of a return wire. We shall install a *sounder* (the electromagnet) and a *key* (the switch) in each city. The key has an extra switch at the side that allows us to open or close the electrical circuit through it, so that we may telegraph in either direction.

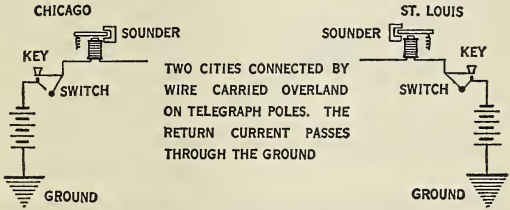


Fig. 205. A simple telegraph line

It is possible to send several messages over the same wire at the same time, to use a typewriter both to send and receive messages, and to send messages under the ocean to foreign countries. All these you will study about in physics.

Explain the principle of the sounder and key used in telegraphy.
How do savages telegraph short distances?
How are the click-clacks of a telegraph sounder translated into words?

475. Electric bell. A bell circuit usually includes several dry cells, a push button, the bell itself, and

the connecting wire (Fig. 206). When one wishes to ring the bell, he pushes the button, and the current flows as indicated by the arrows in the diagram.

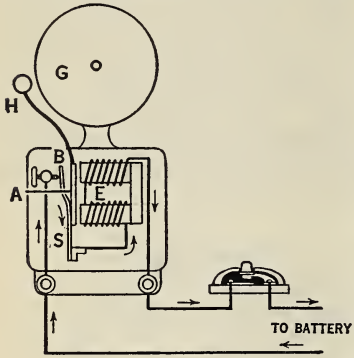


Fig. 206. Bell Circuit

The electromagnet E pulls the soft iron armature A to itself. This causes the hammer H to strike the gong G, and the bell rings one stroke. Notice what happens now at the circuit breaker B. Pulling the armature A to the electromagnet E, breaks the circuit at B. The current ceases to flow, the electromagnet ceases to be a magnet, and the spring S pulls the armature back to its original position.

Everything is now in the same position that it was in before the push button was pressed, and the same cycle of events again takes place. The bell makes another stroke, regains its original position, makes a third stroke, etc. The bell will continue to ring as long as the push button is pressed down.

Name the parts of a bell circuit.
Explain the operation of the bell.
Suggest a change in the wiring of a bell, that will cause the bell to give one stroke only, no matter how long the button is pressed down.

EXPERIMENT 73

Question: Why does an electric bell ring when the button is pushed?

Materials: Dry cell; electric bell; wire.

Directions: (*a*) Examine an electric bell. Trace the path of the wire as it goes through the bell. (See text, Sec. **475**.) Connect the bell to the dry cells, placing a push button in the circuit. Push the button. The bell will ring if the connections are right. Hold the clapper of the bell close to the bell gong. Why does the bell not ring when you push the button?

(*b*) Examine the small set screw that controls the make and break of the current. Move it until you are sure that the bell will not ring. Try it. Explain why the bell no longer rings.

(*c*) Remember how the bell is connected. Can you change the connections so that the bell will be converted into a one-stroke bell. That is, when you push the button, the bell will sound only once. If you think you can do this, try it after consulting your instructor. What change did you make?

Diagram: Show the circuit through a bell (Fig. 206).

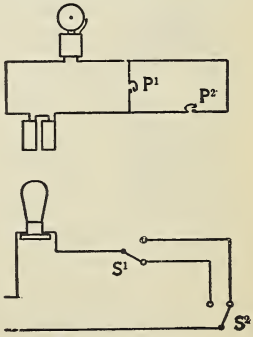
Conclusion: Answer the question.

Practical application: Such electric bells, as you have studied, are used in industry everywhere.

EXPERIMENT 74 (HOME)

Question I: How can I connect a bell so that it will ring when either of two push buttons is pressed?

Question II: How can I connect a light so that it will be lighted or extinguished from either of two buttons? This circuit is used extensively in homes. It is a convenience to be able either to light or extinguish a hall light from the hall or from a switch at the head of the stairs.



Experiment 74

Directions: Examine an electric-light switch in school so that you know just how it works. When you go home, get a paper and pencil and on the paper work out circuits that will enable you to answer both the questions. When you have done this, make a neat copy and show it to your instructor for his approval.

Diagram: Show the two circuits as you have arranged them.

Conclusion: Your diagram is really an answer to the question.

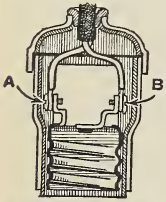
Practical applications: Before installing, wiring installations are always worked out on paper. If you wish a more difficult one, try this. How can a factory be wired so that operating a switch near the door will either turn on or extinguish a light on each of three floors. The lights are also to be controlled from a switch on each floor. Use the smallest amount of wire possible.

Experiment 75

Question: How are electrical appliances connected to the source of current?

Materials: To be supplied by the instructor.

Directions: Your instructor will give you some simple electrical apparatus, such as a lamp socket or a push button and a piece of wire. He will explain to you how it is to be connected. You are then to connect one yourself, and show it for approval. Often a knowledge of how such things are done will enable one to replace at home a wire that has worked loose from an electric iron or a percolator.



Experiment 75

Diagram: Show the work you have done.

Conclusion: Explain why you took the necessary steps in each case.

Practical application: The wiring of electrical appliances is often easy to do, and if done at home will often save waiting for an electrician.

CHAPTER FIFTY-THREE

VARIETIES OF WAVES: RADIO

476. Difference between sound waves and light waves. Since a wave is a vibration, it seems as if there must be some material to vibrate. In the case of sound waves, this is true. Put an electric bell under a glass cover and ring the bell. We can, of course, hear it almost as plainly as if it were in the open air. Pump the air out of the glass cover and the sound disappears (Fig. 207). Sound waves require some material substance to carry them.

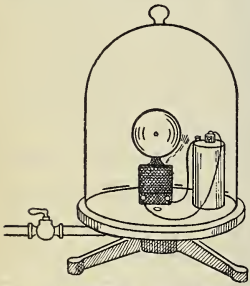


Fig. 207. The air has been pumped out of this glass; therefore it is not possible to hear the bell when rung

When you pump the air out of the glass cover, the bell still remains visible, although there is no material inside the glass cover to carry a vibration. Light waves, then do not require ordinary matter to carry them, nor do the other waves that we shall study about in this chapter. It is fortunate for us that this is true. Otherwise light and radiant heat could not reach us from the sun, for there is no ordinary matter for the greater part of the distance between the sun and us.

Show that sound waves require vibrating matter to transmit them.
Prove that light waves do not require ordinary matter to transmit them.
Why is it important to us that light waves can be transmitted through a vacuum?

477. Never say "I can't." In 1895, newspaper reports told of a German, Dr. Röntgen, who had discovered a wonderful machine that made it possible to see the bones inside our body. Many people laughed at the report, and said, "It can't be done." Nevertheless the report was true, and it could be done. Dr. Röntgen did discover the *X rays.*

Courtesy Victor X-Ray Corp.

Fig. 208. The first X-Ray photograph ever transmitted by telephone wire. The white spot on the third finger is a ring

478. X rays. Dr. Röntgen found a way of making waves similar to those of light, but of much shorter wave length.

These very short waves, called *X rays*, cannot be detected by any of our senses. We can neither see, feel, hear, nor smell them. The easiest way of knowing that they exist is to allow them to fall on a photographic plate, where they produce the same effect as light. They can also be detected by letting them strike a paper covered with calcium tungstate. X rays make this chemical glow.

If we place our hand between the source of these X rays and the calcium tungstate screen, we will see a shadow of our hand on the screen. Our flesh is transparent, while our bones are opaque, to X rays. The shadow will show our bones, a ring, or a needle in the flesh. Surgeons make much use of X rays in such work as locating bullets imbedded in the flesh, and in determining whether broken bones have been properly set.

What are X rays? Of what use are they?
Why can we see our bones in an X-ray photograph?
What use do surgeons make of X rays?

479. Ultra-violet rays. Waves longer than X rays, but shorter than light waves, are known as *ultra-violet rays*. These are the waves in sunlight that cause one to tan. They seem to have a connection with health. So important are these ultra-violet rays that many hospitals have an apparatus for making them artificially. Certain kinds of glass transmit them freely, and hospitals often use this glass in their sun rooms.

480. Electric waves. Next in this series of waves are the light and then the heat waves with which you are familiar. *Electric waves* are the next waves in matter of length. While X-ray, light, and heat waves are measured in very small fractions of an inch, the electric waves are measured in feet, or even miles. The electric waves used in radio work, wireless telephony and telegraphy, are from 300 feet to 90,000 feet in length. We can detect these electric waves only by the aid of some device, such as a radio receiving set. Careful experiments have proved that these waves can be reflected, or refracted, just as can light waves. They differ from light waves mainly in their wave length.

What are ultra-violet rays? What is their use?
What is an electric wave?
What is the main difference between light waves and electric waves?

481. Broadcasting. Before you can pick up electric waves on your radio, they must be *broadcast*, or sent out from some radio station. A detailed study of this is impossible here. It would be too difficult, but a very brief and nontechnical account may be of interest to you.

482. Broadcasting instruments. An *alternator* is used, capable of giving a continuous wave, made up of exceedingly rapid alternations. The wave produced is called a *carrier wave*. The *microphone*, into which the speaker talks, is similar to the tele-

phone transmitter, but is more sensitive. As you know, speaking, singing, or playing into such a microphone will give a varying current. By adding this varying microphone current to the carrier wave, a *modulated wave* is produced. This is led to a long suspended wire, called an *antenna*, and there passes off into the air as a varying electric wave. A simple

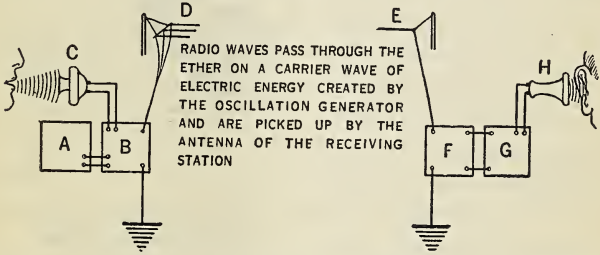


Fig. 209. A simple transmitting and receiving station. A, oscillation generator; B, modulation; C, microphone; D, antenna; E, antenna at receiving station; F, tuner; G, detector; H, telephone receiver

transmitting station and receiving station are shown in Figure 209.

483. Receiving radio waves. The simplest method of detecting these waves that are flying all around us, is to erect an antenna similar to the one used at the transmitting station. This antenna is connected to a crystal that *rectifies* the current; that is, it causes it to flow in one direction only. The current is then passed through a telephone receiver. The energy of the electric waves moves the disk of the

telephone, and sound is produced. A *tuning coil* is also introduced into the circuit so as to make it possible to tune the set to the different wave lengths used by various stations.

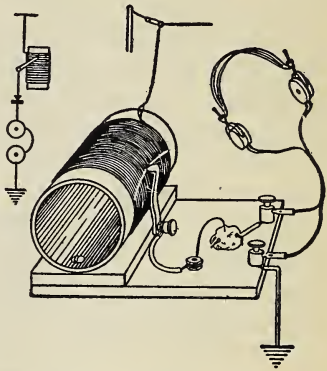


Fig. 210. A simple crystal set; radio receiving hookup

484. Crystal radio sets. The advantages of a crystal receiving set are its cheapness and the good quality of the reproduced sound. Its disadvantages are the necessity of using a telephone receiving headpiece, and the fact that, unless the transmitting station is near by, the amount of electrical energy which the set receives will not be enough to make the telephone receiver give an audible sound.

485. Vacuum-tube radio sets. For these reasons we now usually use a vacuum-tube set. Vacuum tubes receive the energy from a receiving antenna, just as does the crystal, but, by the use of several tubes, it is possible to *amplify* or build up the electrical energy until it can be used to operate a loud speaker. Such sets are now built to operate directly from the house current and can be bought reasonably. They are more convenient than crystal sets.

How is the carrier wave produced in broadcasting?
What causes the modulation in a radio wave?
What is the sending antenna? What is its use?
What is the receiving antenna? What is its use?
How is the alternating radio wave rectified?
What is the use of a tuning coil?
Compare the advantages and disadvantages of a crystal receiving set with those of a vacuum-tube receiving set.

486. As we come to the end of this book, we hope that through observation, experience, and application a little has been added to your store of scientific knowledge and to the methods of acquiring it. It is believed that if you have faithfully followed the text and worked out the experiments, from now on you will be able more intelligently and more efficiently to take up the problems of life that are bound to confront you.

Remember, however, that as yet you have learned but little. The questions that you have asked of Nature thus far are some of the more simple ones, but the methods which you have learned to use are the same as those employed by our greatest experimenter, whose life came to a close as this paragraph was being written.

In appreciation of the toil, the patience, and the skill which was necessary for the production of his many inventions for the benefit of mankind, you are urged to read carefully the biography of Thomas A. Edison, our greatest Questioner of Nature.

CHAPTER FIFTY-FOUR

HEALTH AND EFFICIENCY

487. The value of good health. The new car of the Brown family stood outside the door. Young Jim, just sixteen, with a driver's license in his pocket, ran out of the house and into the car. With

Fig. 211. Men are like automobiles

a screech of agonized gears, he was off, at a speed of fifty miles an hour up the road. He had not looked to see whether the car had water, oil, or even gas. He did not bother to keep down to the thirty-mile-an-hour speed prescribed by the car manufacturer for the first five hundred miles. He stripped the gears, expected the brakes to avoid everything

dangerous, and demanded much more than the new-tried machinery could do.

Our bodies, young, new, and full of life, are the most marvelous machines in the world. Yet we can treat them just as badly as young Jim treated the Brown's new car. The reason that these body machines run for so long, while they are being abused is—they can repair themselves! Patiently and without any fuss our bodies stand for wrong food, late hours, eyestrain, poor posture; but soon there comes a time when our bodies become impatient. Days come when all our fine vigor is dulled, eyes are listless, feet are dragging, pain throbs steadily. These bodies of ours are no longer efficient machines. But because they do so well in making up for our carelessness and disregard of health rules, we do not notice the gradual lessening of power which comes from the abuse of that ability of the body to repair itself. Many people are inefficient because their machinery is running low. The world wants efficient men to run farms, factories, and offices. Doctors advise us to regulate our machinery to its highest point of efficiency so that each one of us can do his full quota of the world's work.

Why is the human body the most marvelous machine in the world?
Why does the "self-repair" function give us the most trouble?
How can we compare Jim's driving to a disregard of health rules?

488. How the body works. The body may be likened to an automobile in the way it is built and works. An automobile is constructed of iron and steel and various other building material. It is able to run because this construction material is put together in the proper arrangement and proportions, and receives the proper amount of fuel fed to it steadily in right amounts. The mixture of fuel must be just right. Besides the proper construction of an automobile and the fuel (gasoline) to propel it, there are other factors which make a smooth-running car. It must be lubricated with oil and its engine cooled with water.

Fig. 212. (1) Building foods

We assume that you have started out in life with a healthy body. This body is constructed of certain materials, being built up daily by the main building material called *protein* which is most plentifully supplied by meat, eggs, milk, fish, beans, and peas. This construction material builds a body of appropriate size and weight, *if* taken in the right amounts in our food (Fig. 212). But protein is not all the body needs. To this structural material must be added fuel which keeps us going. Our fuel comes to us in the *fats and oils* of our food, and in the *carbohydrates* (starch and sugar).

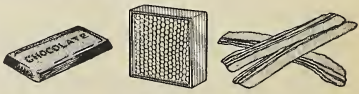


Fig. 212. (2) Energy-producing foods

Besides the building food and the fuel foods, our bodies, for health and vigor, need substances to which the general name of *vitamin* has been given. It has been found that diseases have been caused by the lack of certain vitamins. All this building material and fuel and energy must be taken in the right proportions in order that the machinery of the body work smoothly and efficiently.

Fig. 212. (3) Milk provides building and energy producing foods

489. The composition of the body. As we have said in a preceding paragraph, the body is built largely of protein, fat, and carbohydrates. These substances exist in our food as compounds. Protein is a compound of carbon, oxygen, nitrogen, and sulphur. The fats and carbohydrates are compounds of carbon, oxygen, and hydrogen. Our bodies also contain in small amounts a great many minerals: compounds of iron, lime, phosphorus. If we are to be efficient, we must know how to consume these substances in the right amounts and proportions so that the body can use them to the right advantage (*see* Fig. 213).

If you were going to take a long trip in your automobile, would you add a large amount of iron and steel and other building material to it, or would you fill your gasoline tank with fuel for energy? Why?

THE SIX VITAMINS AND THE FOODS THAT SUPPLY THEM

Name	*What It Is Needed For*	*Chief Foods That Supply It*
Vitamin A	To help prevent colds and other germ infections. To maintain the health and promote the growth of children. To prevent the eye disease called *xerophthalmia.*	Milk, butter, and fresh cheese. Eggs. Green vegetables, such as spinach, watercress, and turnip greens. Yellow vegetables, especially carrots and yellow corn.
Vitamin B (also called B 1 and F)	To preserve nerve health and prevent the nerve disease called *polyneuritis.* To improve appetite. To aid the growth of babies.	Germs of wheat and other cereals. Liver. Yeast. Lettuce. Raw peanuts.
Vitamin C	To maintain a healthy condition of the blood capillaries and prevent the disease called *scurvy.*	Lemons, oranges, and grapefruit. Raw cabbage and sauerkraut. Sprouted grain or peas. Tomatoes, lettuce, watercress. Raw spinach, turnips, or green peppers.
Vitamin D	To aid bone growth and prevent the disease called *rickets,* especially in children To prevent tooth decay. To aid the clotting of blood.	Liver and cod-liver oil. Egg yolk. Snails. Sunshine and (under medical direction) "sunshine lamps."
Vitamin E	To aid the life and growth of babies before birth.	Germ oil of wheat or other grains and many other vegetable oils. Fresh meat and animal fat. Fresh lettuce.
Vitamin F	This is same as Vitamin B.	Same as Vitamin B.
Vitamin G (also called B2)	To prevent the skin disease called *pellagra* and some other skin disorders.	Fresh or evaporated milk. Liver. Green vegetables (even if canned). Bananas. Yeast.

Fig. 213

If you were planning to run an important race, what kind of food would you eat in the weeks before the race? Which foods do we eat for building materials? Energy?

490. Where food comes from. If it were not for plant life upon the face of the earth, there would be no life of any kind because we should not have any

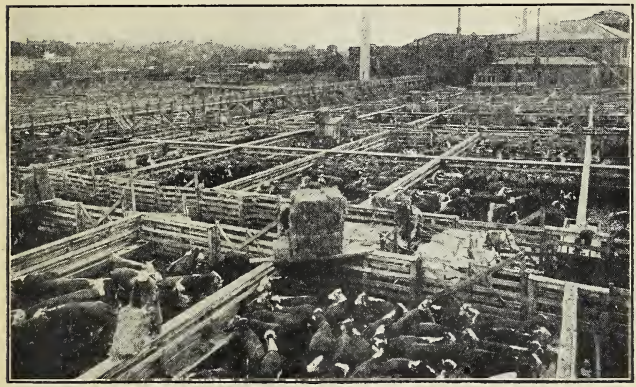


Fig. 214. Feeding cattle at a stockyard. Cattle, sheep, and swine from many states are received at the stockyards. All our food either directly or indirectly comes from plants

building material or fuel for our bodies. We can find no food except that which is part of the bodies of plants, or animals. And animal life is entirely dependent upon plant life (Fig. 214). We could not get meat if the animals which we eat did not have green pastures and meadows to feed upon.

491. How the food gets into the far regions of the body. Our bodies are composed of a jellylike

substance called *protoplasm* which is the essential part of every living organism. This protoplasm is arranged in little masses which we call *cells*. These cells are organized into special forms of tissue: muscles, skin, bone, nerves, blood, hair, and nails. It is these cells that must be fed. They receive their food from the blood stream which flows through the body carrying nourishment to each tiny cell. As the blood passes it, each cell absorbs the food that it needs, and throws off waste material for the blood to carry away to the organs that cast them out of the body. So you see that feeding the body is really feeding many communities of cells, each community being made up of thousands upon thousands of individuals (Fig. 215).

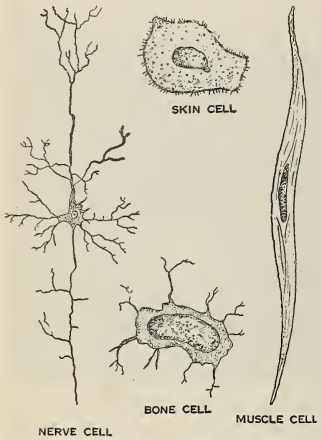


Fig. 215. Every tiny cell of our body must be fed

492. How foods digest. Nature has provided the means whereby we can take complex substances of food into the mouth in solid chunks and convert it into a liquid form to be absorbed by the blood stream and carried to the different cells of the body.

This process of turning solid food into liquid food is called *digestion.*

The first process in digestion is to break the solid food into small particles so that the digestive fluids may easily reach the material (Fig. 216). This is the work of the teeth. If you do not chew your food properly, your stomach has to do the work of the teeth in addition to doing its own work. Certain juices, acting chemically upon our food, make digestion possible. The saliva in the mouth is one of the most important juices. This is another very good reason for chewing so well that each mouthful of food has a good supply of saliva mixed with it. From the mouth the food passes through the esophagus, our swallowing apparatus, and into the stomach (Fig. 217).

Fig. 216. Diagram, showing the teeth. We should chew our food well

493. Stomach digestion. In the stomach muscular walls keep the food slowly churning around. This mixes the food and allows the gastric juice to act upon it. This gastric juice changes the insoluble proteins to simpler substances called *peptones.* The gastric juice contains hydrochloric acid, which is a very necessary aid to digestion in the stomach.

494. Intestinal digestion. When the food has been made into liquid form by the juices from the mouth and the stomach, a little of the liquid food passes into the small intestine. This small intestine is not very "small." In fact, in a full-grown man it is about 20 feet long, coiled and packed into the abdomen. Here the food, now in liquid form, receives further treatment. A great gland, called the *pancreas*, pours in *pancreatic juice* and the *liver* pours in *bile*. In the pancreatic juice are three *enzymes*, or substances, which act chemically to complete the digestion of the proteins, starch, and fats. Other intestinal juices pour in and make a thorough job of digestion.

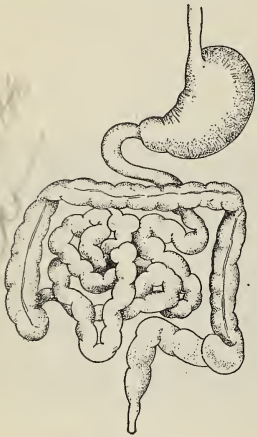


Fig. 217. Diagram of the alimentary canal

Explain the statement, "Animal life is entirely dependent upon plant life."
How are the cells in our bodies fed?
What are two reasons for chewing food well?
Describe stomach digestion.
How does the small intestine complete the process of digestion?

495. Absorption of food. The small intestine is especially fitted for a wonderful process in nature

known as *absorption*. The process of absorption in the intestine is similar to osmosis in plants which we have studied before. The many folds of the intestine have upon their inner surface millions of tiny projections called *villi*, each containing minute blood vessels (Fig. 218). These fingerlike projections absorb the digested starches, sugars, fats, and proteins through the walls of the intestines, and the food becomes a part of the blood stream. The blood carries the absorbed nourishment to the cells of the body.

Fig. 218. Villi highly magnified

496. The fuel pump—the heart. The power house of this transport system is the heart. It is a great, hollow, muscular organ about the size of your fist. It beats constantly, contracting and squeezing out the blood into the arteries about 72 times a minute in a man and more often in children. Food is carried dissolved in the blood. Circulating through the *capillaries* or small blood vessels in the intestinal wall, the blood receives the food and rushes first to the liver. The liver takes out sugar from the blood and stores it away. From the liver the blood rushes on through great veins to pour into the right side of the heart.

The blood carries also to the heart impurities from distant parts of the body. But pure blood which

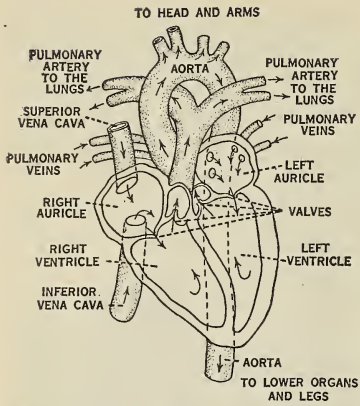


Fig. 219. The pumping station of our circulatory system

has been sent through the oxidizing plant, the lungs, comes to this power house of the heart and is pumped, loaded with food and oxygen, to all parts of the body (Fig. 219). The whole trip around the body from the heart through the lungs and back, and then out to nourish the tissues and back again, has taken less than a quarter of a minute.

What is absorption?
How does the nourishment finally get to each cell of the body?
To what may the action of the heart be compared?

497. Waste substances. All the food that we eat is not digested or changed to liquid form. The chief place of temporary storage for indigestible portions of our food is the large intestine. Here the refuse is kept until it is expelled from the body. It is very necessary that elimination from the large intestine take place every day. If you do not go to the toilet for this function daily, decay will take place and the resulting poison will be carried by the blood stream

throughout your body. When you are feeling very tired, have a headache, or just not "up to the mark," it is very likely because your intestinal habits have not been regular. Exercise, fresh fruits, and vegetables are what the intestines need to perform their work properly.

Although the intestines carry off waste from tissues and much of the wrong kind of food we eat, yet they are not alone in carrying away the waste material from the body. The lungs and the kidneys also expel wastes from the body (Fig. 220). The lungs are a pair of membranous bags covered with a network of tiny blood capillaries, as a leaf is filled with a network of veins. As we breathe out, or exhale, and the lungs contract, water vapor and carbon dioxide, which the blood has brought back from the cells of the tissues, are thereby expelled from the body. In exchange for this waste matter, we inhale into the lungs pure oxygen from the air. The kidneys are organs whose cells take from the blood a number of different waste compounds. This waste matter, dissolved in water, the kidneys expel through a long duct to the bladder, a membranous bag,

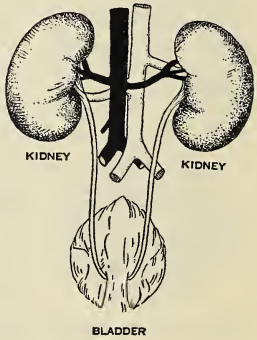


Fig. 220. The kidneys excrete liquid waste

where the liquid, urine, is stored until expelled from the body.

498. Proper attention to excretion. Nature has provided a wonderful system for ridding our bodies of waste and poisonous substances. But this system must be cared for to insure healthy, vigorous bodies, free from poisons. In order that the lungs do their work, we need to breathe fresh air and plenty of it. The rooms in which we live and work must be well ventilated. Exercise in the open air is the very best kind. The intestine is an organ of habit and its action must never be neglected. See that you have such action at least once a day. Never feel embarrassed about going to the toilet. Everybody in the world has the same bodily functions as you have, so there is no reason for your feeling self-conscious. This applies, of course, to the action of the kidneys also. By drinking plenty of water you will assure prompt action on the part of your kidneys in carrying off the poisons from your body. Water is the greatest cleanser in the world—for the inside and the outside of your body.

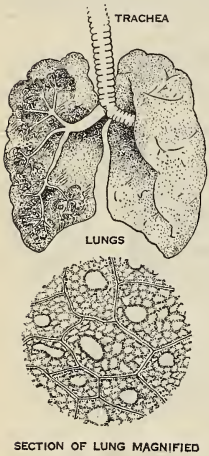


Fig. 221. Air containing oxygen is exchanged for air containing carbon dioxide and water in the lungs

In what organ is the indigestible part of the food collected for expulsion from the body?
Why are your kidneys so important?
What can you do to insure regular action of your intestines?
Name another organ of excretion.
Why are regular toilet habits essential?

499. Appetite *vs.* body needs. Have you ever heard a person say, "I eat what I want; my stomach will digest anything. I believe that the best guide to your food is your appetite"? After a few years you may find that this same person carries around a diet list and eats only certain prescribed things. He has overloaded his stomach and his intestines for so long that if he now wishes to remain alive, he must limit his appetite. He very likely has innumerable aches and pains and is altogether miserable. If this same person had acted sensibly, he would never have had to suffer as he does now.

The appetite is not a safe guide for people any more than it is for a horse. A horse turned loose in a bin of oats will eat himself to death, obeying his appetite. We do not allow a horse to eat so much. Why should we not be as sensible with respect to ourselves as we are with horses?

500. Calories. But you are asking, How may I know just how much protein, fat, and carbohydrates I should consume in a day? Have you ever heard of a calorie? A calorie is a unit for measuring the heat or energy which the body can get from

foods. By assigning a certain number of calories to a certain kind and quantity of food, we can estimate just how much food we need to consume. But not everyone needs the same amount of calories or energy to perform his work. How is this determined? As a result of study on the part of eminent scientists (Professor Chittenden of Yale University; Dr. Graham Lusk of New York University; Professor Atwater of the United States Bureau of Agriculture, and many others) different types of work and the energy needed to perform them have been studied. Their conclusions amount to this, putting it simply: An adult person at moderate work needs $2\frac{1}{2}$ ounces of protein a day for building purposes. In addition, he needs enough fat and carbohydrates to build up his entire energy to 2500–3000 calories. A person doing light work with no exercise in particular would not wear out so much of his body, and would, therefore, not need to eat so much food. On the other hand, a lumberman who works in a cold climate at heavy labor needs as much as 7000 calories a day to keep him strong and warm enough.

Scientists have analyzed hundreds of foods for their fuel value in calories. Many tables of food values have been published. The United States Bureau of Agriculture, in *Bulletin No. 28*, gives the percentage of the protein, fats, and carbohydrates and the number of calories which are found in one pound of each food. For example, one egg contains

PERSONAL FOOD TABLE

Foods as We Eat Them	Weight of Ordinary Helping	Of This the Body Can Use			Yield to the Body in Energy and Heat Units
		Muscle Builder	For Heat and Energy		
		Protein	Fat	Carbohydrates (Starch, Sugar)	
	Ounces	Ounces	Ounces	Ounces	Calories
Pie:					
Apple	4.50	.29	.31	1.44	282.8
Blueberry	3.87	.15	.19	1.50	237.0
Cream	4.00	.18	.46	2.05	380.0
Custard	4.00	.17	.25	1.00	207.5
Coconut cream	3.87	.23	.46	1.04	235.2
Lemon	4.00	.14	.40	1.49	297.2
Mince	5.00	.29	.62	1.90	417.1
Pumpkin	5.00	.15	.15	1.00	177.0
Raisin	5.00	.15	.56	2.36	439.5
Squash	5.00	.22	.42	1.05	262.5
Pork:					
Bacon	1.00	.10	.66	....	188.6
Chops	3.00	.47	.95	....	309.0
Ham croquettes	2.00	.30	.24	.11	111.2
Ham, lean	2.25	.49	.55	....	203.2
Pudding:					
Blanc mange, chocolate	3.50	.10	.30	.49	148.8
Bread	3.50	.19	.42	.57	131.6
Custard	3.25	.16	.16	.35	102.4
Date	2.50	.15	.23	1.40	243.0
Fig	2.75	.11	.17	.82	150.4
Floating island	3.00	.15	.05	.55	118.8
Indian-meal	3.25	.18	.16	.89	165.5
Rice	3.25	.12	.28	.55	149.5
Snow	2.50	.10	.07	.35	75.9
Tapioca	3.25	.11	.10	.92	146.3
and apple	3.25	.01	.00	.95	112.7
Salad:					
Date-and-apple	2.25	.05	.05	.87	121.7
Date-and-walnut	1.25	.63	.16	.62	124.1
Egg with mayonnaise	2.25	.26	.25	.02	100.1
Fruit	2.25	.04	.02	.52	70.4
Potato	2.25	.09	.22	.29	102.1

75 calories and one tablespoon of honey contains 100 calories. On page 451 is a simple table prepared by Mr. Rexford showing the analysis of food by portions. From this you can determine whether you are eating the right food and the proper amount of it.

501. Health and appetite. If you are healthy and strong, you will have a good appetite. But it will not be good for you to gorge or bolt your food down quickly. Why spoil the taste of a good meal? Wise parents will avoid punishing a child near meal time, as it interferes with his proper appetite and upsets his entire digestive system.

Eating well, but not too much, is very important. Our friend, Jim Brown, who ruined the new car, as related some few pages back, did not know the proper use of brakes. He thought of them too late. Use the brakes for controlling your appetite in the right manner and you will be much happier now and later on.

Why is your appetite not an altogether safe guide for eating?
How may we tell how much and what kind of food we should eat?
What is the building substance in our food?
What purposes do the fat and carbohydrates serve?
Why should we come to the table in a happy frame of mind?

502. Importance of blood. In a general way we have learned how the food has to be made liquid and

be absorbed into the blood before it is of any use to the cells of the body. Now we go into a more detailed explanation of just how the blood does its work.

503. Composition of the blood. The blood is mostly water. Over a gallon of water goes through a man's heart every quarter of a minute during rest and twice that or more during exercise. This colorless liquid, or *plasma*, carries millions of little cells, called *corpuscles*. These corpuscles are of two kinds, red and white. The red corpuscles are oxygen boats carrying oxygen to the cells of the body that need it. They are microscopic disks, a little thinner in the middle than on the edges. The white corpuscles can change their shape and go into the smallest spaces. Their work is fighting disease germs, which they do by eating the germs. If the disease germs are the stronger, they overthrow the white corpuscles which finally need a doctor to reinforce them. The plasma carries the carbohydrates and the protein to the tissues and takes the carbon dioxide and the waste material away (Fig. 223).

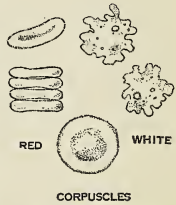


Fig. 223. Red and white blood corpuscles

504. Our cells breathe. We have said that the red corpuscles are oxygen boats. The oxygen has entered the body by way of the lungs. As the blood circulates through the lungs, oxygen unites with a

substance in the red corpuscles to form a chemical compound. A vigorous pump from the heart sends the blood stream, loaded with the red corpuscles, on its journey through the body. The walls of the capillaries are so thin that the hungry cells draw away the oxygen from the red corpuscles.

505. Need of proper exercise. You see that the cells in the body must have an appetite for oxygen. During good, vigorous exercise of the muscles the cells must supply energy. They demand oxygen, and therefore we breathe deeply. A basketball game is about to begin. The members of the team are calm and breathing placidly. But soon the ball is tossed rapidly from one side to the other, fast-stepping feet run pell-mell across the floor, arms heave long shots to the basket. The muscles of the players are working at a greatly increased speed and each little cell is calling out for more energy. There is more demand on the lungs and they must take in more oxygen to meet the demand. Breathing becomes more rapid as the game progresses (Fig. 224).

Tom Smith lived in the city. He was never altogether well, but his father asked him to go for the newspaper each morning before breakfast. He did this year after year and always managed to have a good appetite for breakfast. When he was about ten years old, he discovered that some neighbors near by had their newspaper delivered right to the door. "Why can't I sleep in the morning, Dad?"

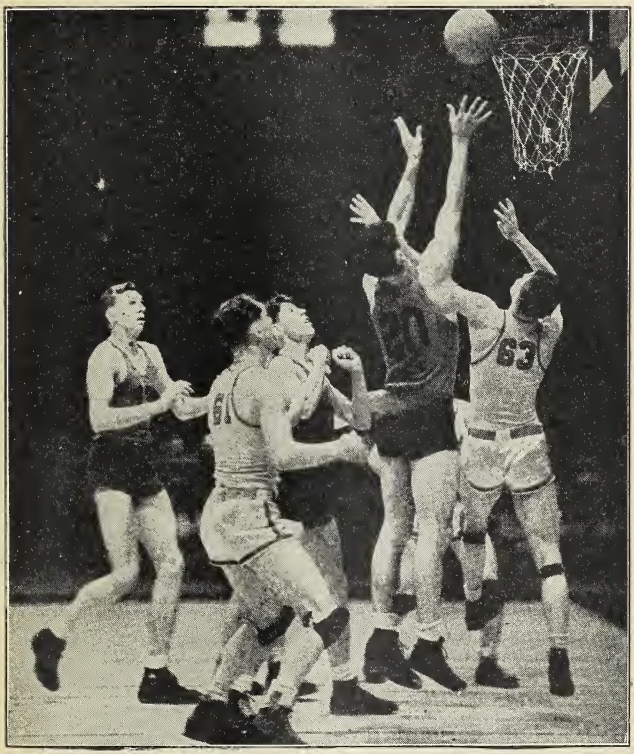


Fig. 224. Basket ball game in action

he asked, "the Gordons have their paper delivered each morning, and so could we." His father replied, "That walk in the morning is for your own good, Tom, and I want you to keep it up because you

cannot do more violent forms of exercise that other boys can do."

Most boys and girls do not have to be reminded about exercising in the open air, but they do not always remember that it should be regular. It is not good to play long and hard one day and then not exercise at all for a week. You cannot store up exercise. A good game, a vigorous swim, a hike in the woods, a run down the road—at least one such form of exercise each day will make of your body a machine fit and vigorous to serve you well with good health and happiness.

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